EXACT

ELECTRONICS, INC.

INSTRUCTION MANUAL

MODELS 501 and 502
FUNCTION GENERATORS

INSTRUCTION MANUAL

MODELS 501 and 502
FUNCTION GENERATORS

EXACT ELECTRONICS INC.
455 S.E. 2nd Avenue, Hillsboro, Oregon 97123 • TEL: (503) 648-6661

IF YOUR INSTRUMENT DOES NOT OPERATE

PLEASE

1. Check operating procedure in manual for proper setup.
2. Check fuse and power supply voltages.
3. Consult the brief troubleshooting guide at the beginning of this manual.
4. Call your Exact representative or factory. Instruments returned to the factory will be accepted only if prior authorization has been given by an Exact representative.

YOUR WARRANTY WILL IN NO WAY BE AFFECTED BY YOUR EFFORT TO FIND THE TROUBLE AND PUT YOUR INSTRUMENT IN EARLY OPERATION. We leave it to your judgment and offer the services of our representatives and our factory to give you the assistance you need.

CLAIM FOR DAMAGED SHIPMENT

The instrument should be inspected as soon as received. If damage has occurred, a claim should be made with the carrier. The claim agent should receive a complete report of damage and a copy sent to Exact. After receiving this report, Exact will advise you of the disposition of the instrument and arrange for its repair or replacement.

WARRANTY

All Exact instruments are fully guaranteed against defective materials and workmanship for one year. Exact's only liability is to repair or replace a defective instrument.

Replacement parts requests should be clearly identified and the instrument serial number given. The needed parts will be air shipped to you within 24 hours.

CONTENTS

SECTION 1	INDEX
SECTION 2	CHARACTERISTICS, SPECIFICATIONS
SECTION 3	FRONT PANEL CONTROLS, OPERATING INSTRUCTIONS, FIRST TIME OPERATION
SECTION 4	CIRCUIT DESCRIPTION
SECTION 5	CALIBRATION, MAINTENANCE
SECTION 6	PARTS LIST
SECTION 7	CIRCUIT DIAGRAMS
SECTION 8	REPRESENTATIVES, DISTRIBUTORS
SECTION 9	ADDENDA

1.0.0 . . . . . .INDEX

2.0.0 . . . . . .CHARACTERISTICS

2.1.0 INTRODUCTION

2.2.0 SPECIFIC CHARACTERISTICS

2.2.1 OUTPUT WAVEFORMS (SYMMETRICAL)

2.3.0 GENERAL CHARACTERISTICS

2.3.1 AMPLITUDE ADJUSTMENTS
2.3.2 FREQUENCY RANGE
2.3.3 FREQUENCY ACCURACY
2.3.4 FREQUENCY STABILITY
2.3.5 FREQUENCY JITTER
2.3.6 OUTPUT AMPLITUDE STABILITY
2.3.7 D.C. REFERENCE STABILITY
2.3.8 FREQUENCY RESPONSE
2.3.9 WAVEFORM SYMMETRY
2.3.10 POWER REQUIREMENTS
2.3.11 MECHANICAL
2.3.12 OPERATING TEMPERATURE

3.0.0 . . . . . OPERATING INSTRUCTIONS

3.1.0 FRONT PANEL FAMILIARITY

3.1.1 LOCATION AND FUNCTION OF CONTROLS

3.2.0 FIRST TIME OPERATION

3.2.1 PROCEDURE FOR PRODUCING BI-POLAR SQUARE
3.2.2 PROCEDURE FOR PRODUCING POSITIVE SQUARE
3.2.3 PROCEDURE FOR PRODUCING NEGATIVE SQUARE
3.2.4 PROCEDURE FOR PRODUCING BI-POLAR SQUARE PULSES
3.2.5 PROCEDURE FOR PRODUCING POSITIVE SQUARE PULSES
3.2.6 PROCEDURE FOR PRODUCING NEGATIVE SQUARE PULSES
3.2.7 PROCEDURE FOR PRODUCING SINE
3.2.8 PROCEDURE FOR PRODUCING TRIANGLE
3.2.9 PROCEDURE FOR PRODUCING RAMP
3.2.10 PROCEDURE FOR PRODUCING REVERSE RAMP
3.2.11 PROCEDURE FOR PRODUCING NON-SYMMETRICAL SINE

1.0.0 . . . . . .INDEX

4.0.0 . . . . . CIRCUIT DESCRIPTION

4.1.0 CIRCUIT DESCRIPTION

4.1.1 BLOCK DIAGRAM
4.1.2 POWER SUPPLY
4.1.3 INTEGRATOR
4.1.4 SCHMITT LEVEL DETECTOR
4.1.5 TIMING AND FEEDBACK CIRCUITRY
4.1.6 SINE SHAPER
4.1.7 ×3 AMP
4.1.8 SQUARE AMPLIFIER

4.2.0 THEORY OF OPERATION

4.2.1 POWER SUPPLY
4.2.2 SHORT CIRCUIT PROTECTION
4.2.3 REGULATOR OPERATION
4.2.4 INTEGRATOR
4.2.5 SCHMITT LEVEL DETECTOR
4.2.6 SINE SHAPER
4.2.7 ×3 AMP
4.2.8 SQUARE AMPLIFIER
4.2.9 SQUARE SELECTOR SWITCH S640

5.0.0 . . . . . CALIBRATION AND MAINTENANCE

5.1.0 FAILURE TO OPERATE

5.2.0 FAILURE TO MEET FACTORY SPECIFICATIONS

5.3.0 CALIBRATION PROCEDURE

5.3.1 POWER SUPPLY
5.3.2 PRELIMINARY TO TIMING
5.3.3 TRIANGLE DC LEVEL ADJUST
5.3.4 TRIANGLE OUTPUT AMPLITUDE ADJUSTMENT
5.3.5 SINE WAVEFORM ADJUSTMENT
5.3.6 FINAL TIMING PRE-CHECK
5.3.7 FINAL TIMING

6.0.0 . . . . . PARTS LIST

1.0.0 . . . . . .INDEX

7.0.0 . . . . . CIRCUIT DIAGRAMS

502-100	BLOCK DIAGRAM
502-101	POWER SUPPLY
502-102	INTEGRATOR
502-103	SCHMITT
502-104	SINE SHAPER
502-105	X3 AMP
502-106	SQUARE AMP

8.0.0 . . . . . REPRESENTATIVES AND OVERSEAS DISTRIBUTORS

9.0.0 . . . . . ADDENDUMS

SECTION 2

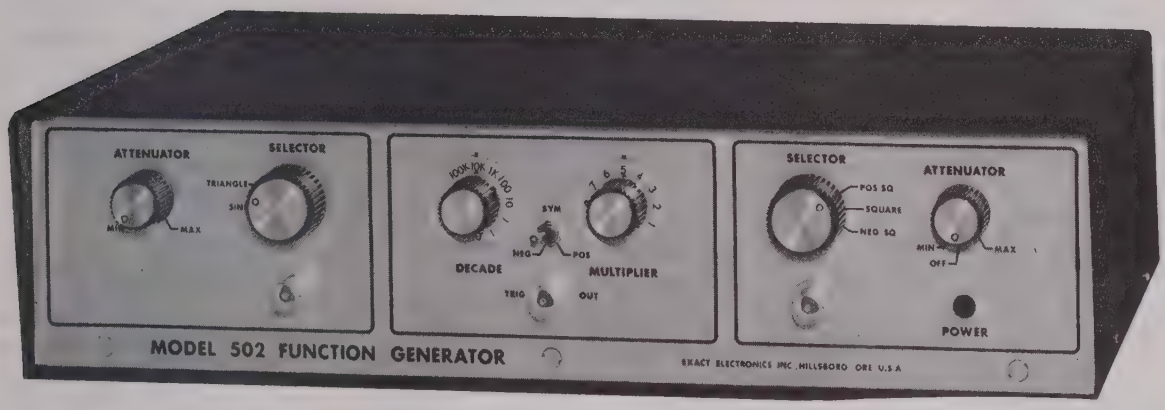
SECTION 2

CHARACTERISTICS AND SPECIFICATIONS

EXACT electronics, inc.

Function Generators • Waveform Synthesizers

MODELS 501 and 502
FUNCTION GENERATORS



- ★ UNITIZED CONSTRUCTION
- ★ INTEGRATED CIRCUITS
- ★ DUAL OUTPUT AMPLIFIERS
- ★ ANODIZED CABINETS
- ★ LIGHT WEIGHT — ONLY 7 LBS.
- ★ LOW POWER DRAIN — ONLY 6 WATTS
- ★ DUAL OUTPUT ATTENUATORS
- ★ 3½ INCHES THIN
- ★ SQUARE - TRIANGLE - SINE - RAMP - N WAVEFORM - PULSES - 0.0001 Hz TO 1MHz

UNITIZED CONSTRUCTION results in LOW-PRICED RELIABILITY. All components are mounted on a one-piece printed-circuit board. The unit is rugged and can withstand greater shock and vibration because components are not mounted on switches or connectors. INTEGRATED CIRCUITS reduce current drain, heat generation, improve over-all performance and reliability and decrease the size of the unit. DUAL AMPLIFIERS are provided with selector switches and attenuators. Amplifier #1 selects bi-polar or offset square waveforms or pulses; #2 amplifier provides selection of triangle, sine or ramp. Both are designed to drive 600-ohm loads at full rated outputs and will drive 50-ohm loads at reduced output amplitudes. The power supplies and amplifiers are SHORT CIRCUIT PROOF. The three-piece cabinet is BRUSHED, ANODIZED aluminum—clear front panel, black cover. Access to the P.C. board for calibration and servicing is made easy by removing only four screws from the cabinet. The instruments are designed to operate over a TEMPERATURE RANGE of +10 to +50°C. APPLICATIONS include square wave generator, sine wave oscillator, pulse generator, ramp and raster generator. Stimulation and simulation in medical research, control signals for aerospace and environmental test are but a few of the many applications for which this rugged versatile and portable function generator was designed. More SOPHISTICATED MODELS are available with such features as triple amplifiers, 50:1 voltage-controlled frequency (available 100:1), gating and triggering and an auxiliary ramp generator for driving the VCF and gating circuits.

EXACT ELECTRONICS INC.
455 S.E. 2nd Avenue, Hillsboro, Oregon 97123 • TEL: (503) 648-6661

MODELS 501 and 502 FUNCTION GENERATORS

SPECIFICATIONS

FREQUENCY
0.001Hz (1000sec) to 1MHz (1microsec)
9 decade ranges
Available 0.00001Hz (100,000secs) to 1MHz (1microsec)

DIAL ACCURACY
± 3% of full scale 0.001 Hz to 100 KHz
± 6% of full scale 100 KHz to 1MHz

FREQUENCY STABILITY
0.05% short term (10 min.)
0.2% long term (24 hrs.)
0.6% per week

JITTER (cycle to cycle)
0.01%

OUTPUTS
SQUARE AMPLIFIER
AMPLITUDES (into 600 ohms)
BI-POLAR SQUARE—adjustable 0 to 14V P-P minimum
POSITIVE/NEGATIVE SQUARE—adjustable 0 to 6V peak minimum
DC REFERENCE—0V ±150mv (typically ±50mv)
AMPLITUDES (into 50 ohms) adjustable
BI-POLAR SQUARE—5V P-P minimum
POSITIVE/NEGATIVE SQUARE—1.5V peak minimum

TRIANGLE, SINE, RAMP AMPLIFIERS (selectable)
AMPLITUDES (into 600 ohms)
TRIANGLE/SINE/RAMP/REVERSE RAMP—adjustable 0 to 9.6V peak minimum
DC REFERENCE LEVEL—0 ±25mv typically less than ±15mv)
AMPLITUDES (into 50 ohms)
TRIANGLE/SINE/RAMP/REVERSE RAMP—adjustable 0 to 5V peak minimum

GENERAL OUTPUT SPECIFICATIONS
AMPLITUDE STABILITY
±0.05% short term (10 minutes)
±0.5% long term (24 hours)

DC REFERENCE STABILITY
±0.05% short term (10 minutes)
±0.2% long term (24 hours)

FREQUENCY RESPONSE (amplitude change with frequency)
±0.1db, 0.0001Hz to 100 KHz
±0.5db to 1MHz (typically 0.2db to 1MHz

SINE WAVEFORM DISTORTION (model 502 only)
Less than 0.6% .001 Hz to 10KHz
Less than 1% 10KHz to 100KHz
Less than 2% 100KHz to 1MHz

TRIANGLE WAVEFORM LINEARITY
±0.1% 0.0001Hz to 10KHz
Less than 1% 10KHz to 1MHz

SQUARE WAVEFORM RESPONSE
Deviation from flatness ±5%
Rise/Falltime less than 50 nanoseconds
Time Symmetry ±1%

TRIGGER OUT
Differentiated square waveform
Amplitude (open circuit)
2V P-P minimum

RAMP WAVEFORM
Linearity—same as Triangle
Falltime and Duration—FOR INFORMATION ONLY, NOT TO BE CONSIDERED AS A SPECIFICATION: Usable only on 10KHz range and below. Duration of ramp waveform less falltime is equal to one half the duration of the triangle waveform. Including falltime, ramp duration varies from 103% to 110% of one half the duration of the triangle. Ramp duration including falltime varies with the setting of the MULTIPLIER dial.

PHYSICAL CHARACTERISTICS
3½"H x 14½"W x 9"D
Weight 7 lbs.
Temperature range—10 to 50°C

Power consumption 6 watts
Input voltage—115 VAC ±10% or 230 VAC ± 20%
Frequency—50 to 400 Hz.
All Specifications Quoted Are At 25°C.

PRICES: (F.O.B. Hillsboro, Oregon)
Model 501 (same as 502, less sine waveform) $350
Model 502 ..... $385
10x slower mod (0.0001Hz to 1MHz) ..... $ 50
100x slower mod—frequency range and price to be negotiated.
Prices and Specifications Subject To Change Without Notice.
Overseas Prices Approximately 5% higher.

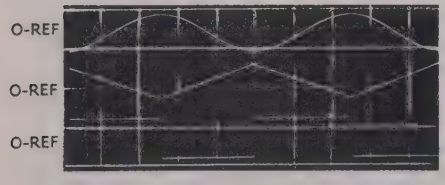


PHOTO SHOWING PHASE RELATIONSHIP OF SQUARE TRIANGLE AND SINE SCOPE TEKTRONIX'S 545 WITH TAPE 1A1 PLUG IN GENERATOR FREQUENCY 100KHz

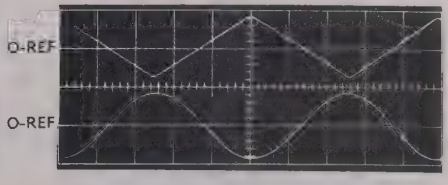
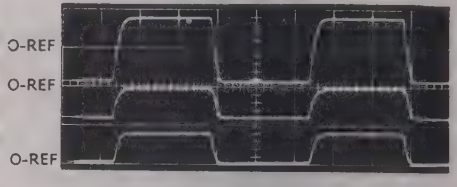
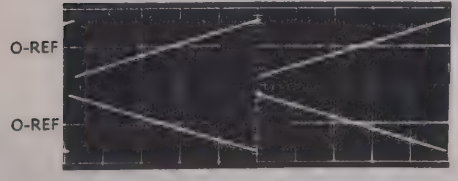


PHOTO SHOWING 1MHz TRIANGLE AND SINE SCOPE VERTICAL SENSITIVITY 5V PER CM. TEKTRONIX 545 WITH TYPE 1A1 PLUG IN.



TOP PHOTO, 1MHz BIPOLAR SQUARE WAVE. CENTER PHOTO, 1MHz NEGATIVE GOING FROM O-REF
LOWER PHOTO 1MHz POSITIVE GOING FROM O-REF.



UPPER PHOTO, 1KHz RAMP WAVEFORM, SYM SW. POS.
LOWER PHOTO, 1KHz REVERSE, RAMP OR "N" WAVEFORM, SYM SW NEG.
RAMP FREQ EXCLUDING FALL TIME IS TWICE THAT OF DIAL SETTINGS. FALL TIME IS NOW FROM APPROX 1% TO 5% OF RAMP TIME. RAMP AND FALL TIME = 110%. SEE PHOTO NO. 5.

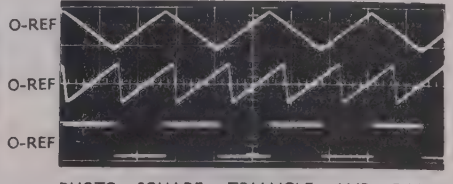
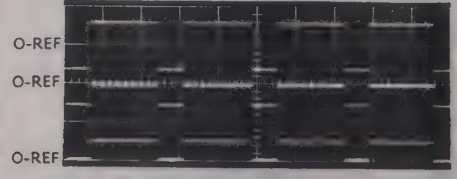


PHOTO SQUARE, TRIANGLE AND RAMP PHASE RELATIONSHIPS. (SYM SW POS, RAMP ONLY)



SQUARE AMP USED AS PULSE GENERATOR UPPER BIPOLAR, CENTER NEGATIVE GOING PULSE, LOWER, POSITIVE GOING PULSE (SYM SW POS) PLACING SYM SW TO NEG ACTUALLY INVERTS ABOVE WAVEFORMS.

2.0.0 . . . . . .CHARACTERISTICS

2.1.0 INTRODUCTION

THE MODELS 501 AND 502 ARE LOW-COST VERSATILE SOLID-STATE FUNCTION GENERATORS CAPABLE OF PROVIDING NUMEROUS OUTPUT WAVEFORMS AT ANY DESIRED FREQUENCY FROM 0.001Hz TO 1MHz (0.00001 TO 1MHz WITH OPTIONAL MODIFICATION).

NOTE: SPECIFICATIONS BELOW ARE NOT NECESSARILY FIRM; PLEASE REFER TO THE SPEC SHEET IN FRONT OF THIS SECTION FOR CURRENT SPECIFICATIONS.

2.2.0 SPECIFIC CHARACTERISTICS

2.2.1 OUTPUT WAVEFORMS (SYMMETRICAL)

A. SQUARE WAVEFORM

1. BI-POLAR SQUARE WAVE AMPLITUDE 16V P-P OPEN CIRCUIT, 14V P-P INTO 600 OHMS, 5V P-P INTO 50 OHMS.

   +SQUARE WAVE AMPLITUDE +7V PEAK OPEN CIRCUIT, 6V PEAK INTO 600 OHMS, 1.5V INTO 50 OHMS.

   -SQUARE WAVE AMPLITUDE -7V PEAK OPEN CIRCUIT, 6V PEAK INTO 600 OHMS, 1.5V P-P INTO 50 OHMS.

2. RISE AND FALL TIMES TYPICALLY 36NSEC. THESE TIMES WILL VARY SLIGHTLY AT HIGHER FREQUENCIES WHEN DRIVING A CAPACITIVE LOAD OF MORE THAN 470PF, BUT WILL REMAIN LESS THAN 50NSEC AT MAXIMUM AMPLITUDE WITH NORMAL LOADS APPLIED OF 600 OHMS OR GREATER.

3. D.C. REFERENCE LEVEL 0 TO ±150MV (TYPICALLY ±50MV).

4. DEVIATION FROM FLATNESS TYPICALLY LESS THAN 5% OVER ENTIRE FREQUENCY RANGE.

5. OUTPUT IMPEDANCE TYPICALLY 100 OHMS.

B. TRIGGER OUT

1. DIFFERENTIATED SQUARE WAVE OF 2V P-P OPEN CIRCUIT (TYPICALLY 3.5V P-P). AMPLITUDE VARIES BETWEEN DECADES.

2. OUTPUT IMPEDANCE 150 OHMS.

C. SINE WAVEFORM

1. AMPLITUDE 10V P-P OPEN CIRCUIT, 9.6V P-P INTO 600 OHMS, 5V P-P INTO 50 OHMS.

2. OUTPUT IMPEDANCE TYPICALLY 50 OHMS.

2.2.1 C. (CONTINUED)

3. DISTORTION LESS THAN .6% FROM 0.001Hz TO 10KHz, LESS THAN 1% 10KHz TO 100KHz, LESS THAN 2% 100KHz TO 1MHz.

4. D.C. REFERENCE LEVEL 0±25mv (TYPICALLY LESS THAN ±15mv).

D. TRIANGLE WAVEFORM

1. AMPLITUDE 10V P-P OPEN CIRCUIT, 9.6V P-P INTO 600 OHMS, 5V P-P INTO 50 OHMS.

2. OUTPUT IMPEDANCE TYPICALLY 50 OHMS.

3. LINEARITY IS TYPICALLY LESS THAN .1% .001 TO 10KHz, 1% TO 1MHz.

4. D.C. REFERENCE LEVEL ZERO VOLTS ±25mv (TYPICALLY LESS THAN ±15mv).

E. SQUARE PULSE (NON-SYMMETRICAL) OBTAINED FROM SQUARE WAVEFORM OUTPUT BY PLACING SYM SWITCH IN EITHER POSITIVE OR NEGATIVE POSITION. SAME CHARACTERISTICS AS SQUARE.

1. BI-POLAR PULSE SAME CHARACTERISTICS AS SQUARE. SEE PARA 2.2.1 A.

2. POSITIVE SQUARE PULSE SAME CHARACTERISTICS AS SQUARE. SEE PARA 2.2.1 A.

3. NEGATIVE SQUARE PULSE SAME CHARACTERISTICS AS SQUARE. SEE PARA 2.2.1 A.

4. DUTY CYCLE 9:1 (SYM SWITCH NEG) OR 1:9 (SYM SWITCH POS) AT X10 END OF MULTIPLIER DIAL AND 90:1 (SYM SWITCH NEG) OR 1:90 (SYM SWITCH POS) AT THE X1 END OF THE MULTIPLIER DIAL. THE DUTY CYCLE IS VARIABLE FROM 9:1 TO 90:1 BY VARYING THE MULTIPLIER DIAL FROM X10 TO X1.

5. PULSE WIDTH IS EQUAL TO THE RAMP FALLTIME.

F. RAMP OBTAINED FROM TRIANGLE OUTPUT (USABLE ONLY TO 20 KHz). THE RAMP WAVEFORM IS USABLE TO THE MAXIMUM DIAL SETTING OF 10KHz BUT PLACING THE SYM SWITCH TO POS OR NEG DOUBLES THE FREQUENCY.

1. AMPLITUDE 10V P-P OPEN CIRCUIT, 9.6V P-P INTO 600 OHMS.

2.2.1 F. (CONTINUED)

2. OUTPUT IMPEDANCE TYPICALLY 50 OHMS.

3. LINEARITY SEE PARA 2.2.1 D (3).

4. FALLTIME LESS THAN 10% AT X10 END OF MULTIPLIER DIAL, VARIABLE TO LESS THAN 1% AT X1 END OF MULTIPLIER DIAL FROM 0.001Hz TO 10KHz.

5. D.C. REFERENCE LEVEL SEE PARA 2.2.1 D (4).

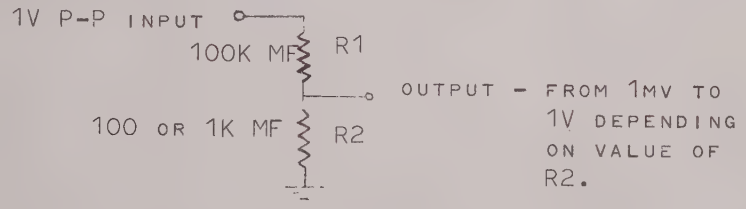
NOTE: A NON-SYMMETRICAL SINE IS AVAILABLE AT THE SINE OUTPUT WHEN THE SYM SWITCH IS SWITCHED TO EITHER NEG OR POS. THE SINE PORTION HAS THE SAME CHARACTERISTICS AS THE SINE, WHILE THE FALLTIME PORTION HAS THE SAME CHARACTERISTICS AS THE RAMP FALLTIME. THE DUTY CYCLE IS THE SAME AS THE RAMP.

2.3.0 GENERAL CHARACTERISTICS

2.3.1 AMPLITUDE ADJUSTMENTS

A. THE AMPLITUDE ON BOTH OUTPUT AMPLIFIERS IS CONTINUOUSLY VARIABLE FROM THE MAXIMUM SPECIFIED AMPLITUDE TO APPROXIMATELY ZERO VOLTS FOR ALL WAVEFORMS.

B. IF USED BELOW 1 VOLT AND SPIKING OR 60-CYCLE JITTER BECOMES A PROBLEM, USE THE FOLLOWING ATTENUATOR CONFIGURATION.



2.3.2 FREQUENCY RANGE 0.001Hz TO 1MHz (OPTIONAL 0.00001Hz TO 1MHz TO 0.0001Hz TO 1MHz). CONTINUOUSLY VARIABLE.

2.3.3 FREQUENCY ACCURACY TYPICALLY LESS THAN ±3% OF FULL SCALE FROM 0.001Hz TO 10KHz, LESS THAN ±6% OF FULL SCALE 10KHz TO 1MHz.

2.3.4 FREQUENCY STABILITY (DRIFT) ±.05% SHORT TERM (10 MINUTES) ±.2% LONG TERM (24 HOURS), ±.6% PER WEEK.

2.3.5 FREQUENCY JITTER TYPICALLY LESS THAN 0.01% CYCLE-TO-CYCLE.

2.3.6 OUTPUT AMPLITUDE STABILITY TYPICALLY LESS THAN ±.05% SHORT TERM (10 MINUTES), LESS THAN ±.5% LONG TERM (24 HOURS).

2.3.7 D.C. REFERENCE STABILITY TYPICALLY LESS THAN ±.05% SHORT TERM (10 MINUTES), LESS THAN ±.5% LONG TERM (24 HOURS).

2.3.8 FREQUENCY RESPONSE ±.1DB 0.001Hz TO 100KHz, ±.5DB 100KHz TO 1MHz.

2.3.9 WAVEFORM SYMMETRY (TIME) TYPICALLY LESS THAN ±1% LONG TERM.

2.3.10 POWER REQUIREMENTS

A. LINE VOLTAGE 115 ±10% OR 230V AC ±20%.

B. LINE FREQUENCY 50 TO 400 CPS.

C. POWER CONSUMPTION 6 WATTS.

D. PROTECTION TRANSFORMER PRIMARY IS FUSED AND UNIT IS GROUNDED. THE POWER SUPPLIES AND THE AMPLIFIERS ARE SHORT-CIRCUIT PROTECTED.

2.3.11 MECHANICAL

A. CONSTRUCTION - THREE-PIECE ALUMINUM ALLOY CABINET. CHASSIS AND COVER BRUSHED AND BLACK ANODIZED. FRONT PANEL BRUSHED AND ANODIZED CLEAR WITH BLACK LETTERING.

B. NET WEIGHT 7 POUNDS.

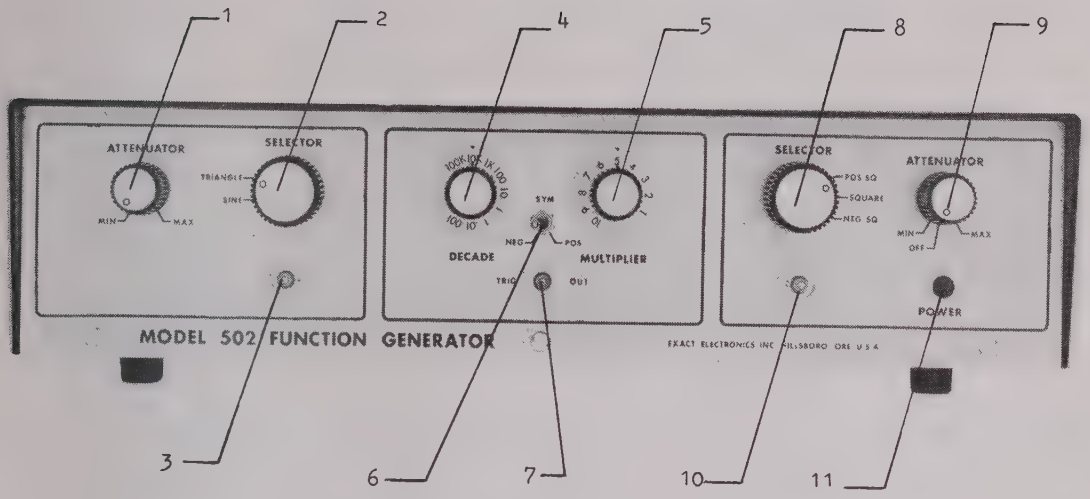
C. DIMENSIONS 14-1/2 × 9 × 3-1/3 INCHES.

2.3.12 OPERATING TEMPERATURE +10°C TO 50°C OPERATING ONLY.

SECTION 3

SECTION 3

FRONT PANEL CONTROLS
OPERATING INSTRUCTIONS
FIRST-TIME OPERATION



3.1.0 FRONT PANEL FAMILIARITY

3.1.1 LOCATION AND FUNCTION OF CONTROLS

1. ATTENUATOR FOR SINE, TRIANGLE OR RAMP.
2. OUTPUT SELECTOR FOR SINE, TRIANGLE AND RAMP IF SYM SWITCH IS EITHER POS OR NEG.
3. OUTPUT CONNECTOR FOR SINE, TRIANGLE OR RAMP.
4. DECADE SWITCH SELECTS ANY ONE OF THE NINE DECADE FREQUENCY RANGES.
5. MULTIPLIER DIAL MULTIPLIES DECADE FREQUENCY. VARIABLE FREQUENCY DIAL.
6. SYM SWITCH USED TO CONVERT TRIANGLE INTO RAMP OR SQUARE INTO PULSE.
7. TRIG OUT PROVIDES TRIGGER PULSE FOR EXTERNAL EQUIPMENT.
8. SQUARE WAVE SELECTOR SELECTS BI-POLAR SQUARE, POSITIVE SQUARE, NEGATIVE SQUARE OR PULSE IF SYM SWITCH IS EITHER POSITIVE OR NEGATIVE.
9. SQUARE WAVE ATTENUATOR. ALSO INCORPORATES POWER ON/OFF SWITCH.
10. OUTPUT CONNECTOR FOR SQUARE OR PULSE OUTPUTS.
11. POWER ON/OFF INDICATOR LIGHT.

3.2.0 FIRST-TIME OPERATION

3.2.1 PROCEDURE FOR PRODUCING BI-POLAR SQUARE

A. Set function generator as follows

SELECTOR	SQUARE
DECADE	1KHz
MULTIPLIER	X10
SQUARE ATTENUATOR	MAX (full CW)
SYM	OFF
MONITOR	Connect square waveform output to a monitor oscilloscope
TRIG OUT	Connect trig out jack to the external trigger input of monitor oscilloscope. Use coaxial cable.

B. Set oscilloscope as follows

VERTICAL SENSITIVITY	5V/cm
INPUT COUPLING	DC
SWEEP TIME	100 microsec/cm
TRIGGER	EXTERNAL POSITIVE

3.2.2 PROCEDURE FOR PRODUCING POSITIVE SQUARE

Settings same as 3.2.1 with exception of SELECTOR switch, which should be set to POS SQ.

3.2.3 PROCEDURE FOR PRODUCING NEGATIVE SQUARE

Settings same as 3.2.1 with exception of SELECTOR switch, which should be set to NEG SQ.

3.2.4 PROCEDURE FOR PRODUCING BI-POLAR SQUARE PULSES

A. Set function generator as follows

SELECTOR	SQUARE
SYM	NEG or POS
SQ OUTPUT ATTENUATOR	MAX (full CW)
DECADE	1KHz
MULTIPLIER	X10
MONITOR	SQUARE OUTPUT
TRIGER OUT	to external trigger input of oscilloscope

3.2.4 (CONTINUED)

B. SET MONITOR OSCILLOSCOPE AS FOLLOWS

VERTICAL SENSITIVITY	5V/CM
INPUT COUPLING	DC
SWEEP TIME	100 MICROSEC/CM
TRIGGER	EXTERNAL POSITIVE

3.2.5 PROCEDURE FOR PRODUCING POSITIVE SQUARE PULSES

SETTINGS SAME AS 3.2.4 WITH EXCEPTION OF SELECTOR SWITCH, WHICH SHOULD BE SET TO POS SQ.

3.2.6 PROCEDURE FOR PRODUCING NEGATIVE SQUARE PULSES

SETTINGS SAME AS 3.2.4 WITH EXCEPTION OF SELECTOR SWITCH, WHICH SHOULD BE SET TO NEG SQ.

3.2.7 PROCEDURE FOR PRODUCING SINE

A. SET FUNCTION GENERATOR AS FOLLOWS

SELECTOR	SINE
DECADE	1KHz
MULTIPLIER	X1
SINE ATTENUATOR	MAX (FULL CW)
SYM	OFF
MONITOR	CONNECT SINE OUTPUT TO OSCILLOSCOPE VERTICAL INPUT
TRIGGER OUT	CONNECT TRIG OUT TO OSCILLOSCOPE EXTERNAL TRIGGER INPUT.

B. SET OSCILLOSCOPE AS FOLLOWS

VERTICAL SENSITIVITY	5V/CM
INPUT COUPLING	DC
SWEEP TIME	100 MICROSEC/CM
TRIGGER	EXT POS

3.2.8 PROCEDURE FOR PRODUCING TRIANGLE

SETTINGS SAME AS 3.2.7 WITH EXCEPTION OF SELECTOR SWITCH, WHICH SHOULD BE SET TO TRIANGLE.

3.2.9 PROCEDURE FOR PRODUCING RAMP

A. SET FUNCTION GENERATOR AS FOLLOWS

SELECTOR	TRIANGLE
DECADE	1KHz
MULTIPLIER	×1
TRIANGLE ATTENUATOR	MAX (FULL CW)
SYM	POS
MONITOR	CONNECT TRIANGLE OUTPUT TO MONITOR OSCILLOSCOPE VERTICAL INPUT
TRIGGER OUT	CONNECT TRIG OUT TO MONITOR OSCILLOSCOPE EXTERNAL TRIGGER INPUT

B. SET MONITOR OSCILLOSCOPE AS FOLLOWS

VERTICAL SENSITIVITY	5V/CM
INPUT COUPLING	DC
SWEEP TIME	100 MICROSEC/CM
TRIGGER	EXTERNAL POS

3.2.10 PROCEDURE FOR PRODUCING REVERSE RAMP (N-TYPE WAVEFORM)

SETTINGS SAME AS 3.2.9 WITH EXCEPTION OF SYM SWITCH, WHICH SHOULD BE SET TO NEG.

3.2.11 PROCEDURE FOR PRODUCING NON-SYMMETRICAL SINE

SETTINGS SAME AS 3.2.9 WITH EXCEPTION OF SELECTOR SWITCH, WHICH IS SET TO SINE.

SECTION 4

SECTION 4

CIRCUIT DESCRIPTION

4.1.0 CIRCUIT DESCRIPTION

4.1.0 BLOCK DIAGRAM (REFER TO DRAWING 502-100, SECTION 7).

4.1.2 POWER SUPPLY

THE REGULATED POWER SUPPLY PRODUCES ALL OPERATING VOLTAGES REQUIRED BY THE INSTRUMENT. IT INCLUDES REGULATED +12V AND -12V AND UNREGULATED +17V AND -17V AND GROUND CONNECTIONS. THE POWER SUPPLY IS SHORT CIRCUIT PROTECTED.

4.1.3 INTEGRATOR

THE PURPOSE OF THE INTEGRATOR IS BASICALLY TO INTEGRATE A SQUARE WAVEFORM INTO A LINEAR TRIANGLE WAVEFORM.

4.1.4 SCHMITT LEVEL DETECTOR

THE FUNCTION OF THE SCHMITT LEVEL DETECTOR IS TO PRODUCE A SQUARE WAVE WHICH IS FED TO THE INTEGRATOR TO OBTAIN THE TRIANGLE WAVEFORM.

4.1.5 TIMING AND FEEDBACK CIRCUITRY

A. THE PURPOSE OF THE TIMING AND FEEDBACK CIRCUITRY IS TO CONNECT THE INTEGRATOR AND LEVEL DETECTOR TOGETHER TO MAKE A FREE-RUNNING GENERATOR PRODUCING SQUARE AND TRIANGLE WAVEFORMS PLUS A METHOD FOR VARYING THE FREQUENCY SIMULTANEOUSLY.

B. THE TIMING CIRCUITRY CONNECTS THE SCHMITT LEVEL DETECTOR TO THE INTEGRATOR CIRCUIT. THE COMBINATION OF THESE CIRCUITS PRODUCES A FREE-RUNNING OSCILLATOR CIRCUIT, PRODUCING A SQUARE WAVE AND A TRIANGLE WAVEFORM. (THE TIMING CIRCUITRY ALSO PROVIDES A METHOD OF CONTROLLING AND VARYING THE FREQUENCY OF THE FREE-RUNNING OSCILLATOR CIRCUIT.)

4.1.6 SINE SHAPER

THE SINE SHAPER IS BASICALLY AN AMPLIFIER UTILIZING THE NON-LINEAR CHARACTERISTICS OF SEMICONDUCTOR DIODES TO CAUSE THE AMPLIFIER GAIN TO VARY NON-LINEARLY. THE TRIANGLE WAVEFORM IS FED INTO THE SINE SHAPER AND THE RESULTANT SINE WAVEFORM IS PRODUCED.

4.1.7 X3 AMP

THE X3 AMP IS BASICALLY A DIFFERENTIAL AMPLIFIER. IT AMPLIFIES AT ITS INPUT THE SELECTED SINE OR TRIANGLE WAVEFORM TO PRODUCE 9.6V P-P TRIANGLE/SINE AT THE OUTPUT AT A MOD-

4.1.7 X3 AMP (CONTINUED)

ERATELY LOW OUTPUT IMPEDANCE. THE AMPLIFIER IS CAPABLE OF PROVIDING 9.6V P-P INTO A 600-OHM LOAD, OR A WAVEFORM OF MUCH LESSER AMPLITUDE INTO A 50-OHM LOAD. THIS AMPLIFIER IS SHORT CIRCUIT PROTECTED.

4.1.8 SQUARE AMPLIFIER

A. THE SQUARE AMPLIFIER IS BASICALLY AN ELECTRONIC SWITCH. IT IS DRIVEN BY THE SQUARE WAVEFORM FROM THE SCHMITT (LEVEL DETECTOR). THE SWITCH IS CAUSED TO SWITCH FROM ONE SATURATED STATE TO ANOTHER BY THE INPUT SQUARE WAVE. THE USE OF SUCH A CIRCUIT PRODUCES A GOOD SQUARE WAVEFORM WITH RELATIVELY FAST RISE AND FALL TIMES.

B. OVERSHOOT, RINGING AND DROOP ARE LIMITED BY THE USE OF EXTREMELY SHORT LEADS AND PEAK LIMITING OF BOTH NEGATIVE AND POSITIVE EXTREMES. ALTHOUGH THE SPECIFICATION OF DEVIATION FROM FLATNESS IS 5%, THE WAVEFORM VIRTUALLY HAS NO DEVIATION. LIKE THE X3 AMPLIFIER, THIS AMPLIFIER WILL DRIVE A 600-OHM LOAD AT 15V P-P AND A 50-OHM LOAD AT A MUCH LOWER AMPLITUDE. THIS AMPLIFIER IS VIRTUALLY INDESTRUCTIBLE BECAUSE LIKE THE POWER SUPPLY, IT IS SHORT CIRCUIT PROTECTED.

4.2.0 THEORY OF OPERATION

4.2.1 POWER SUPPLY (REFER TO DRAWING 502-101).

THE POWER SUPPLY PRODUCES ±12V, ±17V TO THE INSTRUMENT AND CONSISTS OF TWO BASICALLY IDENTICAL SERIES REGULATORS WHICH PRODUCE A LOW RIPPLE ±12V FROM AN UNREGULATED ±17V SOURCE.

A. LINE VOLTAGE IS APPLIED TO TRANSFORMER T100 THROUGH THE ON/OFF SWITCH S100 AND FUSE F100. THE TRANSFORMER PRODUCES 17V AC WHICH IS FED TO RECTIFIER ASSEMBLIES D100 AND D101 WHICH PRODUCE THE UNREGULATED +17V. CAPACITORS C100 AND C110 PROVIDE FILTERING OF THE UNREGULATED +17V.

B. BECAUSE BOTH THE +12V AND THE -12V REGULATORS ARE BASICALLY IDENTICAL, ONLY THE POSITIVE REGULATOR WILL BE DISCUSSED HERE. Q100 IS BASICALLY A CURRENT SOURCE. THE MAXIMUM CURRENT IS LIMITED BY RESISTOR R100. R100 (10K BASE CURRENT LIMITING RESISTOR) WILL ALLOW APPROXIMATELY 1.7MA BASE CURRENT TO FLOW.

4.2.2 SHORT CIRCUIT PROTECTION (UNREGULATED +17V AND REGULATED +12V).

WITH AN AVERAGE BETA OF 100 ON Q100, A MAXIMUM CURRENT OF 170MA CAN FLOW THROUGH Q100. NORMAL DRAIN IS APPROXIMATELY 100MA. IN THE EVENT OF A SHORT CIRCUIT ON THE +12V OR +17V SUPPLY, Q100 WILL DRAW 170MA AND NO MORE. THIS MEANS THAT THE COLLECTOR VOLTAGE OF Q100 COULD BE PLACED AT GROUND, DEVELOPING 17V COLLECTOR TO EMITTER AT 170MA WHICH WOULD BE APPROXIMATELY 300MV OF POWER. IF THE SHORT WERE NOT REMOVED, DAMAGE TO Q100 COULD RESULT. SHORT CIRCUIT DURATION IS AT LEAST ONE MINUTE OR LONGER. NORMALLY WITH Q100 SATURATED, APPROXIMATELY 17V WILL BE APPLIED TO THE REGULATOR.

4.2.3 REGULATOR OPERATION (+12V SUPPLY)

A. A REFERENCE VOLTAGE OF APPROXIMAGELY 9V IS APPLIED TO ONE SIDE OF DIFFERENTIAL AMPLIFIER Q160 AND Q180. THE REFERENCE ZENER D161 IS CONNECTED THROUGH D120 AND VOLTAGE DIVIDER R121 AND R122 TO APPLY APPROXIMATELY 8V ON C120 INITIALLY TO INSURE STARTING VOLTAGE FOR THE REGULATOR.

B. Q160 WILL SUPPLY CURRENT TO THE BASE OF Q120 WHICH WILL IN TURN SUPPLY VOLTAGE TO THE BASE OF Q140.

C. EMITTER FOLLOWER Q140 SUPPLIES THE REGULATED +12V. THE EMITTER VOLTAGE OF Q140 IS FED THROUGH VOLTAGE DIVIDER R181.

THE ARM OF R182 IS ADJUSTABLE AND PROVIDES APPROXIMATELY 9V AT THE BASE OF Q180 WHEN Q140 EMITTER VOLTAGE IS 12V.

D. IF THE OUTPUT VOLTAGE TRIES TO INCREASE DUE TO A DECREASE IN LOAD OR AN INCREASE IN LINE VOLTAGE, THE BASE VOLTAGE AT Q180 WILL INCREASE, CAUSING THE COLLECTOR CURRENT OF Q180 TO INCREASE AND THE COLLECTOR CURRENT OF Q160 TO DECREASE. THE BASE VOLTAGE OF Q160 IS FIXED BY ZENER DIODE D161 AT APPROXIMATELY +9V.

E. WITH A DECREASE IN COLLECTOR CURRENT OF Q160, THE VOLTAGE AT THE BASE OF Q120 WILL INCREASE CAUSING LESS COLLECTOR CURRENT TO FLOW THROUGH Q120 AND R123, LOWERING THE VOLTAGE AT THE BASE OF Q140 UNTIL THE EMITTER VOLTAGE HAS RETURNED TO +12V. THE +12V ADJUST IS USED TO CALIBRATE THE POWER SUPPLY TO +12V ±5MV. THE NEGATIVE 12V SUPPLY OPERATES IN ESSENTIALLY THE SAME MANNER.

4.2.4 INTEGRATOR (REFER TO DRAWING 502-102)

THE INTEGRATOR CIRCUIT IS UTILIZED TO PRODUCE A VERY LINEAR OUTPUT TRIANGLE BY INTEGRATING THE SQUARE WAVEFORM PRODUCED BY THE SCHMITT LEVEL DETECTOR. IT IS BASICALLY AN OPERATIONAL AMPLIFIER.

A. THE OPERATIONAL AMPLIFIER Q240 (RCA-3030 IC) HAS A MATCHED FET INPUT (Q200 AND Q230) TO OBTAIN VERY SLOW INTEGRATION. Q250 AND Q270 FORM A COMPLEMENTARY OUTPUT EMITTER FOLLOWER TO OBTAIN A MODERATELY LOW OUTPUT IMPEDANCE TO DRIVE THE ASSOCIATED CIRCUITRY.

B. A SQUARE WAVEFORM IS APPLIED TO A TIMING RESISTOR (R208 THROUGH R222 SELECTED BY THE DECADE SWITCH) THROUGH A VOLTAGE DIVIDER, R204-R205). R204 IS THE MULTIPLIER ADJUST WHICH VARIES THE AMPLITUDE OF THE SQUARE WAVEFORM APPLIED TO THE TIMING RESISTORS AND THE FREQUENCY WITHIN THE DECADE. IT IS APPLIED TO THE INVERTING SIDE OF THE OPERATIONAL AMPLIFIER THROUGH EMITTER FOLLOWER Q200.

C. Q200 AND Q230, MATCHED FET'S, PROVIDE AN EXTREMELY HIGH INPUT IMPEDANCE INTO THE OPERATIONAL AMFLIFIER. FEEDBACK FROM THE OUTPUT EMITTER FOLLOWER, Q250 AND Q270, IS ACCOMPLISHED THROUGH THE INTEGRATING CAPACITOR, C251 THROUGH C255, SELECTED BY THE DECADE SWITCH AND IS ALSO APPLIED TO THE INVERTING SIDE OF THE OPERATIONAL AMPLIFIER. THIS PROVIDES NEGATIVE FEEDBACK, FORCING THE SUMMING JUNCTION TO REMAIN AT VIRTUAL GROUND. THE INT BAL CONTROL IS ADJUSTED TO BALANCE THE TWO INPUTS OF THE DIFFERENTIAL OPERATIONAL AMPLIFIER.

D. WITH A +SQUARE WAVEFORM APPLIED TO THE TIMING RESISTOR, THE OUTPUT OF THE OPERATIONAL AMPLIFIER WILL TRY TO SWITCH NEGATIVE IMMEDIATELY.

E. THE +SQUARE WAVEFORM APPLIED TO THE TIMING RESISTOR AND CONNECTED TO THE SUMMING JUNCTION WILL ALLOW A FINITE CURRENT TO FLOW THROUGH THE TIMING RESISTOR. THIS CURRENT WILL BE VERY CONSTANT AS THE SQUARE WAVEFORM VOLTAGE IS CONSTANT AND THE SUMMING JUNCTION IS HELD AT VIRTUAL GROUND DUE TO THE EXTREMELY HIGH GAIN AND NEGATIVE FEEDBACK. DUE TO THE NEGATIVE FEEDBACK THROUGH THE INTEGRATING CAPACITOR, THE OUTPUT MUST CHARGE THE INTEGRATING CAPACITOR.

F. AS THE TIMING CURRENT FLOWS FROM THE SUMMING JUNCTION, AN EQUAL BUT OPPOSITE CURRENT WILL BE APPLIED THROUGH

4.2.4 F. (CONTINUED)

THE INTEGRATING CAPACITOR IN THE FEEDBACK LOOP. THIS FEEDBACK CURRENT THROUGH THE INTEGRATING CAPACITOR MUST REMAIN CONSTANT AS THE INPUT TIMING CURRENT IS CONSTANT. THIS WILL CAUSE THE OUTPUT TO RISE NEGATIVE AT A CONSTANT RATE CHARGING THE CAPACITORS AT A CONSTANT CURRENT.

G. THE OUTPUT IS CONNECTED TO THE LEVEL DETECTOR, PRODUCING THE SQUARE WAVEFORM THAT IS BEING INTEGRATED. WHEN THE INTEGRATOR OUTPUT REACHES A PREDETERMINED LEVEL, THE LEVEL DETECTOR WILL CHANGE STATE AND INVERT THE SQUARE WAVEFORM APPLIED TO THE INTEGRATOR TIMING RESISTOR. THIS WILL IN TURN REVERSE THE OPERATION DESCRIBED AND THE INTEGRATOR OUTPUT WILL REVERSE AND START RISING POSITIVELY, THUS PRODUCING A LINEAR TRIANGLE WAVEFORM AT THE OUTPUT.

H. BY SWITCHING IN DIFFERENT TIMING RESISTORS AND INTEGRATING CAPAICTORS, THE FREQUENCY CAN BE CHANGED IN DECADE STEPS. BY VARYING THE MULTIPLIER DIAL, THE SQUARE WAVEFORM AMPLITUDE APPLIED TO THE INTEGRATOR IS CHANGED CAUSING A LINEAR CHANGE IN TIMING CURRENT AND THEREBY CHANGING FREQUENCY. BY SWITCHING RESISTORS AND CAPACITORS WITH THE DECADE SWITCH AND ADJUSTING THE MULTIPLIER DIAL, ANY DESIRED FREQUENCY FROM 0.00001 TO 1MCS MAY BE OBTAINED.

J. THE SYM SWITCH S201 IS PROVIDED TO PRODUCE NON-SYMMETRICAL OPERATION REQUIRED FOR THE VARIOUS NON-SYMMETRICAL WAVEFORMS SUCH AS THE RAMP, REVERSE RAMP AND SQUARE WAVEFORM PULSES. SWITCH S201 ENABLES THE SQUARE WAVEFORM TO BE CONNECTED DIRECTLY TO THE SUMMING JUNCTION BY-PASSING THE TIMING RESISTOR.

K. WHEN S201 IS SWITCHED TO THE NEGATIVE POSITION, R203 AND D203 CONNECT THE APPLIED NEGATIVE SQUARE WAVEFORM DIRECTLY TO THE SUMMING JUNCTION. THE POSITIVE SQUARE WAVEFORM IS APPLIED TO THE JUNCTION AS EXPLAINED IN PARA 3.2.3. D203 WILL CONDUCT ONLY WHEN THE SQUARE WAVEFORM IS NEGATIVE.

L. WHEN THE SQUARE WAVEFORM SWITCHES NEGATIVE, THE TIMING RESISTOR WILL BE BY-PASSED BY R203 AND D203. R203, A 1K RESISTOR, WILL CAUSE A MUCH LARGER TIMING CURRENT TO FLOW. THE OUTPUT OF THE INTEGRATOR WILL RISE POSITIVE MUCH FASTER AS A RESULT OF THE INCREASED TIMING CURRENT.

4.2.4 (CONTINUED)

M. WHEN THE OUTPUT OF THE INTEGRATOR REACHES THE TRIP POINT OF THE LEVEL DETECTOR, THIS SQUARE WAVEFORM WILL REVERSE POLARITY AS PREVIOUSLY DESCRIBED. WITH THE SQUARE WAVEFORM NOW POSITIVE, D203 WILL BE REVERSE BIASED AND THE INTEGRATOR WILL INTEGRATE AT THE SAME RATE AS IN THE NORM POSITION.

4.2.5 SCHMITT LEVEL DETECTOR (REFER TO DRAWING 502-103)

A. THE SCHMITT IS USED IN CONJUNCTION WITH THE INTEGRATOR TO PRODUCE A SQUARE WAVEFORM. IN CONJUNCTION WITH THE INTEGRATOR IT PRODUCES FREE-RUNNING SQUARE AND TRIANGLE WAVEFORMS.

B. THE INPUT TO THE SCHMITT IS CONNECTED TO THE OUTPUT OF THE INTEGRATOR AS DESCRIBED IN PARA 3.2.2. Q300 IS A CONSTANT CURRENT SOURCE FOR DIFFERENTIAL AMPLIFIER Q310 AND Q320. Q330 AND Q340 FORM A SECOND DIFFERENTIAL AMPLIFIER WHICH IS CONNECTED TO Q310 AND Q320 DIFFERENTIAL AMPLIFIER TO FORM A HIGH-GAIN AMPLIFIER CIRCUIT.

C. THE OUTPUT VOLTAGE SWING OF Q330 AND Q340 COLLECTORS ARE BOTH CLAMPED BY A DIODE BRIDGE TO APPROXIMATELY ±1.5V P-P.

D. POSITIVE FEEDBACK IS USED TO OBTAIN VERY FAST SWITCHING ONCE THE TRIP POINT IS REACHED.

E. WITH THE INPUT RISING POSITIVE, Q310 WILL TURN OFF AND Q320 WILL TURN ON. ONCE Q310 IS TURNED OFF, THE COLLECTOR VOLTAGE OF Q310 WILL GO NEGATIVE. THIS WILL IN TURN CAUSE Q340 BASE TO GO NEGATIVE CAUSING Q340 TO TURN OFF AND Q330 TO CONDUCT HARDER. Q330 COLLECTOR VOLTAGE WILL GO FARTHER NEGATIVE CAUSING Q320 BASE TO GO NEGATIVE AND Q320 TO CONDUCT HARDER. Q340 (POSITIVE FEEDBACK) COLLECTOR VOLTAGE WAS INCREASED POSITIVE DUE TO Q340 TURNING OFF. THIS IN TURN CAUSES THE OUTPUT TO THE TIMING RESISTOR TO SWITCH TO ITS POSITIVE STATE.

F. A POSITIVE INPUT WAVEFORM CAUSES THE OUTPUT TO SWITCH POSITIVE WHEN THE TRIP INPUT POINT IS REACHED (INVERTING). IN THIS MANNER, THE INTEGRATOR AND THE SCHMITT CREATE A FREE-RUNNING SQUARE AND TRIANGLE WAVEFORM SIMULTANEOUSLY.

G. Q330 COLLECTOR SIGNAL IS APPLIED TO THE OUTPUT EMITTER FOLLOWER WHICH DRIVES THE SQUARE AMPLIFIER AND PRODUCES THE TRIGGER OUT SIGNAL.

4.2.6 SINE SHAPER

THE SINE SHAPER IS BASICALLY A DIFFERENTIAL OPERATIONAL AMPLIFIER WITH NON-LINEAR FEEDBACK WHICH WILL PRODUCE A LOW-DISTORTION SINE WAVEFORM FROM A LINEAR TRIANGULAR INPUT.

A. TRANSISTORS Q400, Q410 AND Q420, Q430 ARE TWO DIFFERENTIAL AMPLIFIERS CONNECTED TOGETHER TO OBTAIN HIGH GAIN.

B. WITH THE INPUT RISING AT A CONSTANT SLOPE (POSITIVE TRIANGLE), Q430 COLLECTOR VOLTAGE WILL GO NEGATIVE. AS THE OUTPUT RISES NEGATIVELY THE FEEDBACK NETWORK VOLTAGE DIVIDER WILL ESSENTIALLY CONNECT SMALLER AND SMALLER RESISTANCE ACROSS THE FIXED GAIN FEEDBACK RESISTOR R472, THUS CAUSING THE GAIN TO DECREASE AS THE OUTPUT VOLTAGE RISES NEGATIVELY.

C. WHEN THE INPUT TRIANGLE CHANGES SLOPE, THE OUTPUT WILL SIMPLY REVERSE POLARITY AND RISE POSITIVE PRODUCING THE SAME NON-LINEAR ACTION.

D. THE CONSTANTLY CHANGING GAIN OF THE AMPLIFIER WILL PRODUCE THE REQUIRED SINE WAVEFORM AT THIS OUTPUT.

E. Q450 EMITTER FOLLOWER APPLIES THIS SIGNAL DIODE SHAPER NETWORK TO THE OUTPUT VIA Q460, Q470 EMITTER FOLLOWER.

4.2.7 X3 AMPLIFIER

THE X3 AMPLIFIER SELECTS THE TRIANGLE AND SINE WAVEFORMS AND AMPLIFIES THEM TO 9.6V P-P AT A LOW OUTPUT IMPEDANCE. THE INPUT TO THE X3 AMPLIFIER IS CONNECTED THROUGH SELECTOR SWITCH S500 TO THE SINE AND TRIANGLE WAVEFORMS.

A. Q400, Q510 AND Q520, Q530 ARE CONNECTED TOGETHER TO PRODUCE HIGH GAIN.

B. Q550 IS AN EMITTER FOLLOWER WHICH IN CONJUNCTION WITH Q540 IS A CONSTANT CURRENT SOURCE, TRANSFERS THE SIGNAL TO THE OUTPUT EMITTER FOLLOWER Q560 AND Q570. R573 SETS THE GAIN OF THE AMPLIFIER TO PRODUCE 10V P-P AT THE OUTPUT.

4.2.8 SQUARE AMPLIFIER

THE SQUARE AMPLIFIER IS ESSENTIALLY A HIGH-SPEED SWITCH WHICH PRODUCES A 14V P-P OUTPUT SQUARE WAVE AT LESS THAN 50 NANOSECONDS RISE AND FALL TIMES.

4.2.8 (CONTINUED)

A. THE SQUARE WAVEFORM GENERATED IN THE SCHMITT IS FED INTO THIS SQUARE AMPLIFIER INPUT. WITH THE SQUARE WAVEFORM IN ITS POSITIVE STATE, Q600 WILL TURN ON, CAUSING Q620 TO GO NEGATIVE. THIS NEGATIVE SIGNAL AT Q620 CAUSES Q620 TO SATURATE, THUS PULLING THE COLLECTOR VOLTAGE OF Q620 POSITIVE VERY RAPIDLY. THE POSITIVE INPUT SIGNAL WOULD HOLE Q610 OFF AS LONG AS THE INPUT REMAINED POSITIVE. WHEN THE INPUT SWITCHES NEGATIVE, Q630 COLLECTOR WILL SWITCH NEGATIVE VERY RAPIDLY.

B. R633 APPLIES THIS SQUARE WAVEFORM THROUGH SELECTOR SWITCH S640 TO THE OUTPUT EMITTER FOLLOWER.

4.2.9 SQUARE SELECTOR SWITCH S640

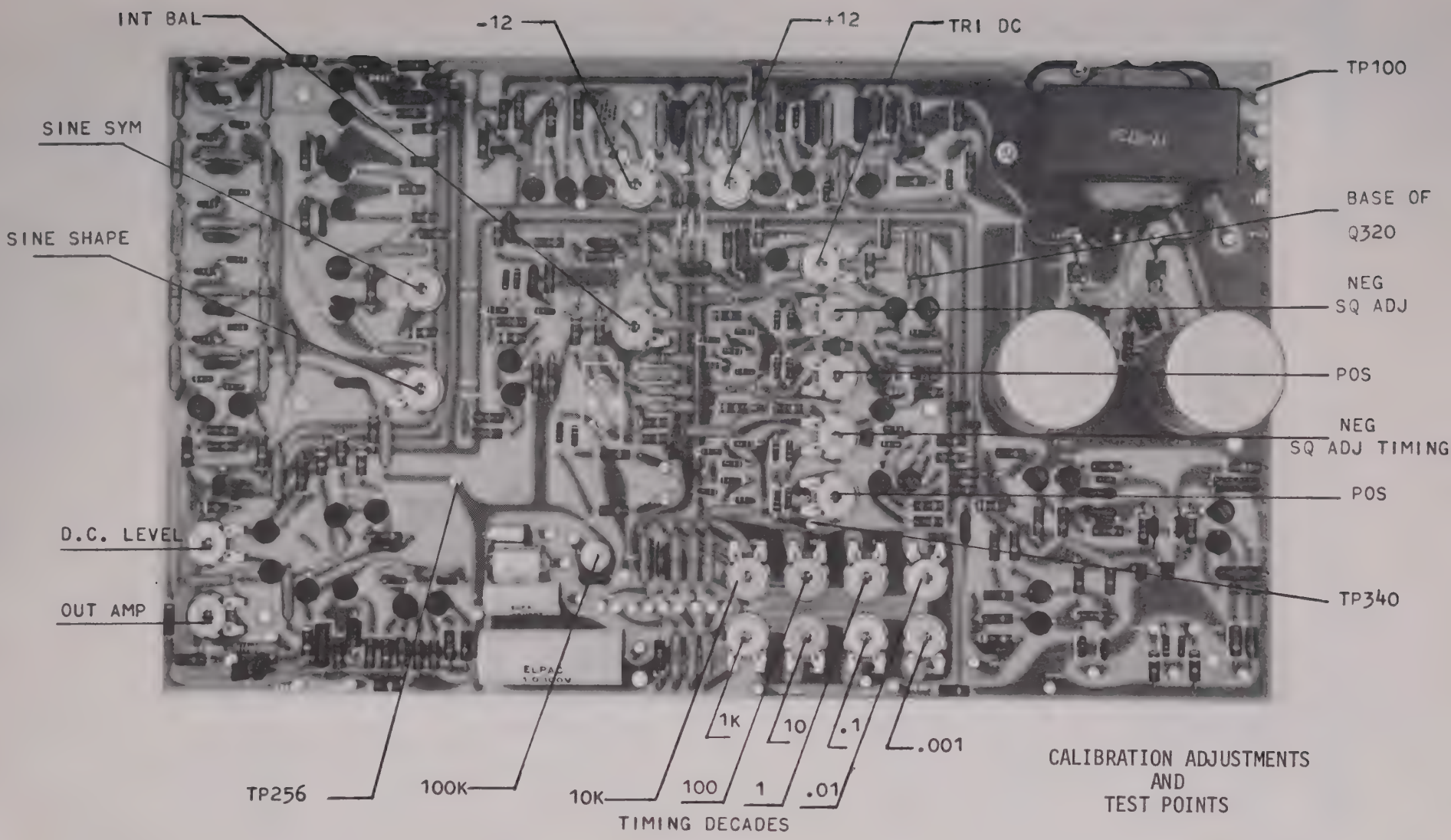
A. WHEN SWITCHED TO THE POS SQ POSITION, A DIODE IS IN SERIES WITH THE SQUARE WAVE BEING APPLIED TO THE OUTPUT EMITTER FOLLOWER. THIS WILL ALLOW SIGNAL TO PASS IN ONLY THIS POSITION.

B. WHEN THE SELECTOR IS PLACED IN THE NEG SQ POSITION, D651 ALLOWS ONLY THE NEGATIVE PORTION OF THE SQUARE WAVEFORM TO PASS TO THE EMITTER FOLLOWER AND ON TO THE OUTPUT.

SECTION 5

CALIBRATION AND MAINTENANCE

SECTION 5



CALIBRATION ADJUSTMENTS
AND
TEST POINTS

5.0.0 . . . . . .CALIBRATION AND MAINTENANCE

5.1.0 FAILURE TO OPERATE

READ OPERATING INSTRUCTIONS TO INSURE A THOROUGH UNDERSTANDING OF ALL FRONT PANEL CONTROLS.

SHOULD INSTRUMENT FAIL TO HAVE AN OUTPUT FROM EITHER OF THE TWO AMPLIFIER OUTPUTS, CHECK THE FOLLOWING.

A. UNPLUG INSTRUMENT AND CHECK 117V 3AG 1/2 AMP FUSE LOCATED ON REAR PANEL.

B. REMOVE COVER AND CHECK FOR 117V ON TP100.

IF TROUBLE IS NOT LOCATED IN ABOVE STEPS, FOLLOW CALIBRATION PROCEDURE UNTIL TROUBLE IS LOCATED.

5.2.0 FAILURE TO MEET FACTORY SPECIFICATIONS

CHECK THE FOLLOWING.

A. PROPER OPERATING INSTRUCTIONS IN SECTION 2.0.0 TO INSURE A THOROUGH UNDERSTANDING OF ALL FRONT PANEL CONTROLS.

B. PERFORM ALL STEPS OF CALIBRATION PROCEDURE. IF INSTRUMENT STILL DOES NOT MEET SPECIFICATIONS, CONTACT FACTORY AND ARRANGE TO RETURN FOR A COMPLETE CHECK-OUT AND EVALUATION.

5.3.0 CALIBRATION PROCEDURE

THE FOLLOWING TEST EQUIPMENT OR SUITABLE EQUIVALENTS OF KNOWN ACCURACY ARE REQUIRED FOR COMPLETE CALIBRATION OF THE TYPES 501 AND 502 FUNCTION GENERATORS.

A. OSCILLOSCOPE, DC TO 100MHz, TEKTRONIX 585 WITH 1A1 PLUG-IN

B. DISTORTION ANALYZER, B&W 410

C. VARIAC POWERSTAT

D. FREQUENCY COUNTER, CMC 607

E. DIFFERENTIAL VOLTMETER, MEDISTOR A-75

F. VOM, SIMPSON 260

G. 600-OHM PURLY RESISTIVE LOAD

5.3.1 POWER SUPPLY

THE INSTRUMENT SHOULD BE ON FOR AT LEAST 15 MINUTES BEFORE ANY OF THE FOLLOWING ADJUSTMENTS IS MADE.

A. USING DIFFERENTIAL VOLTMETER, ADJUST +12 VOLTS AND -12 VOLTS TO 12V ±5MV.

B. REGULATION CHECK

VARY LINE VOLTAGE FROM 95 TO 130V AC WHILE OBSERVING EACH SUPPLY VOLTAGE. SUPPLY VOLTAGE SHOULD REMAIN CONSTANT WITHIN ±15MV.

C. RIPPLE CHECK

SET OSCILLOSCOPE CONTROLS AS FOLLOWS.

VERTICAL SENSITIVITY	MAX
INPUT COUPLING	AC
SWEEP TIME	10MSEC/CM
TRIGGER	CONTINUOUSLY RUNNING

MEASURE RIPPLE OF EACH SUPPLY. SHOULD BE LESS THAN 5MV.

5.3.2 PRELIMINARY TO TIMING

A. INTERNAL BALANCE

SET FUNCTION GENERATOR CONTROLS AS FOLLOWS.

DECADE	1K
MULTIPLIER	X1
SYM	OFF

SET OSCILLOSCOPE CONTROLS AS FOLLOWS.

VERTICAL SENSITIVITY	2 VOLTS/CM
INPUT COUPLING	DC
SWEEP TIMING	100µSEC
TRIGGER	EXTERNAL POSITIVE
MONITOR	TP256

ADJUST INT BAL TO OBTAIN A SYMMETRICAL TRIANGLE ±1% AT TP256.

5.3.2 (CONTINUED)

B. SQUARE WAVEFORM SYMMETRY

SET FUNCTION GENERATOR CONTROLS AS FOLLOWS.

SELECTOR	SQUARE
MULTIPLIER	×10
DECADE	1K
SYM	OFF
ATTENUATOR	MAX (CW)

SET OSCILLOSCOPE CONTROLS AS FOLLOWS.

VERTICAL SENSITIVITY	5V/cm
INPUT COUPLING	DC
SWEEP TIMING	10µsec
TRIGGERING	EXTERNAL POSITIVE
MONITOR	BASE OF Q320

1. ADJUST POSITIVE SQUARE AND NEGATIVE SQUARE ADJUST TO OBTAIN MINIMUM AMPLITUDE WITH EQUAL POSITIVE AND NEGATIVE AMPLITUDES, ZERO REFERENCE.

2. ADJUST POSITIVE TIMING SQUARE ADJUST AND NEGATIVE SQUARE TIMING ADJUST TO OBTAIN MAXIMUM EQUAL PEAK-TO-PEAK SQUARE WAVEFORM AT TP340.

3. ADJUST SYMMETRY OF SQUARE WAVEFORM AT TP340 BY ADJUSTING + OR - TIMING SQUARE ADJUST TO OBTAIN CORRECT SYMMETRY ±.5%.

4. ADJUST SYMMETRY USING INT BAL WHILE MULTIPLIER IS SET AT ×1. MONITOR SQUARE WAVEFORM OUTPUT WHILE ADJUSTING SYMMETRY TO 50/50 ±.5%.

5. REPEAT STEPS 1 THROUGH 4.

5.3.3 TRIANGLE DC LEVEL ADJUST

USING VOM, MONITOR TP256, ADJUST TRI DC LEVEL TO 0 VOLTS DC ±20mv.

5.3.4 TRIANGLE OUTPUT AMPLITUDE ADJUSTMENT

A. SET FUNCTION GENERATOR CONTROLS AS FOLLOWS.

DECADE	1K
MULTIPLIER	×1
SYM	OFF

5.3.4 (CONTINUED)

B. SET OSCILLOSCOPE CONTROLS AS FOLLOWS.

VERTICAL SENSITIVITY	2V/CM
INPUT COUPLING	DC
SWEEP TIMING	100µSEC
TRIGGER	EXTERNAL POS
MONITOR	TRIANGLE OUTPUT ACROSS 600-OHM LOAD.

C. ADJUST OUTPUT AMPLITUDE TO OBTAIN 9.6V P-P TRIANGLE ±100MV.

D. ADJUST OUTPUT DC LEVEL FOR 0 V DC ±20MV USING VOM.

5.3.5 SINE WAVEFORM ADJUSTMENT

A. ATTACH DISTORTION METER ACROSS 600-OHM LOAD AT SINE OUTPUT.

B. OUTPUT ATTENUATOR TO MAX.

C. OUTPUT SELECTOR TO SINE.

D. DECADE 1K.

E. MULTIPLIER X1.

F. ADJUST SINE SYMMETRY AND SINE SHAPER FOR MINIMUM DISTORTION. WILL RUN BETWEEN 0.4% AND 0.6%.

G. SET MULTIPLIER TO X10 AND CHECK THAT SINE WAVEFORM DISTORTION IS LESS THAN 0.6%.

H. CHECK SINE DISTORTION AND WAVE SHAPE AT ALL RANGES.

J. CHECK SINE AMPLITUDE AT 10K, 100K, 1MHZ TO CONFIRM AMPLITUDE FREQUENCY RESPONSE. 100K AMPLITUDE SHOULD BE 9.6V P-P ±.1DB INTO 600-OHM LOAD.

5.3.6 FINAL TIMING PRE-CHECK

THE FOLLOWING SHOULD BE CHECKED TO CONFIRM PROPER OPERATION BEFORE FINAL TIMING ADJUSTMENTS ARE MADE.

A. MEASURE SQUARE WAVEFORM RISE AND FALL TIMES AT SQUARE WAVEFORM OUTPUT. SHOULD BE LESS THAN 50NSEC.

5.3.6 (CONTINUED)

B. WITH CONTROLS SET AS FOLLOWS, MEASURE RAMP FALLTIME. SHOULD BE LESS THAN 10% OF DURATION AT 10KHz.

MONITOR TRIANGLE OUTPUT.

SELECTOR	TRIANGLE
SYMMETRY	POSITIVE
DECADE	1K
MULTIPLIER	×10

C. SET MULTIPLIER TO ×1 END AND CHECK THAT RAMP FALLTIME IS STILL LESS THAN 3% OF DURATION.

D. WITH MONITOR TRIG OUT (OPEN CIRCUIT, NO LOAD), SYM SWITCH OFF, CHECK FOR DIFFERENTIATED SQUARE WAVEFORM OF GREATER THAN 2V P-P ON ALL DECADE SETTINGS.

5.3.7 FINAL TIMING

NOTE: BEFORE FINAL TIMING IS STARTED, CHECK SQUARE WAVE SYMMETRY ON 1K × 1, 1K × 10, 10K × 1, 10K × 10, 100K × 1 AND 100K × 10 TO INSURE THAT POSITIVE AND NEGATIVE PORTIONS OF SQUARE WAVEFORM ARE OF EQUAL DURATION, ±1%. IF THEY ARE NOT, REPEAT STEP 5.3.2 BEFORE CONTINUING.

A. MULTIPLIER DIAL ALIGNMENT

1. SET FUNCTION GENERATOR CONTROLS AS FOLLOWS.

DECADE	1K
MULTIPLIER	×1
MONITOR	SQUARE OUTPUT
SELECTOR	SQUARE

2. CONNECT FREQUENCY COUNTER ACROSS 600-OHM LOAD TO SQUARE WAVEFORM OUTPUT.

3. ADJUST TIMING DECADE RANGE 1K POTENTIOMETER TO APPROXIMATELY CENTER.

4. ADJUST MULTIPLIER DIAL TO OBTAIN 1KHz ±.5% AS READ ON COUNTER.

5. LOOSEN ALLEN SCREWS ON MULTIPLIER DIAL, BEING CAREFUL NOT TO MOVE TIMING SHAFT. ADJUST MULTIPLIER DIAL UNTIL "×1" IS EXACTLY ABOVE AND BELOW THE TWO INDEX MARKS. TIGHTEN ALLEN SCREWS, AGAIN BEING CAUTIOUS NOT TO MOVE TIMING SHAFT.

5.3.7 A. (CONTINUED)

6. TURN TIMING DIAL TO X10 END, ALIGNING "10" DIRECTLY ABOVE AND BELOW INDEX MARKERS. ADJUST 1K TIMING POTENTIOMETER LOCATED IN TIMING DECADE SECTION TO OBTAIN 10KHz, ±.5% AS READ ON FREQUENCY COUNTER.

7. TURN MULTIPLIER BACK TO X1 AND CHECK THAT FREQUENCY IS STILL 1K ±.5%. LIKELY THIS WILL BE OFF A LITTLE IN WHICH CASE STEPS 5.3.7 1 THROUGH 6 WILL HAVE TO BE REPEATED UNTIL FREQUENCY IS ON AT BOTH ENDS OF DIAL ±.5%.

B. FINAL DECADE ADJUSTMENTS

1. ADJUST DECADE RANGES TO READ THE FOLLOWING FREQUENCIES AS MONITORED ON FREQUENCY COUNTER.

DECADES	FREQUENCY
100K	100KHz ±.5%
10K	10KHz ±.5%
1K	1KHz ±.5%
100	100Hz ±.5%
10	20Hz ±.5%
1	1Hz ±.5%
.1	0.1Hz ±.5%
.01	0.01Hz ±.5%
.001	0.001Hz ±.5%

2. TURN MULTIPLIER DIAL TO X1 AND CHECK THAT ALL DECADE RANGES ARE WITHIN THE SPECIFICATIONS IN SPEC SHEET LOCATED AT THE FRONT OF SECTION 2.

SECTION 6

PARTS LIST

SECTION 6

6.0.0 . . . . . PARTS LIST

MANUFACTURER CODE

AB	ALLEN BRADLEY	MTR	MOTOROLA
IRC	INTERNATIONAL RESISTOR CO.	IR	INTERNATIONAL RECTIFIER
UC	UNION CARBID	RCA	RCA SEMICONDUCTOR DIV.
CD	CONTINENTAL DEVICE	FAR	FAIRCHILD

CIRCUIT REF.	DESCRIPTION	EXACT PART	MFG
	CAPACITORS		
C100	2700MF 25V 36D27G025	290-024	SPRAGUE
C110	2700MF 25V 36D27G025	290-024	SPRAGUE
C120	10MF 20V	290-031	KEMET
C140	.05 DISC CAP	283-010	RMC(MALLORY)
C160	10MF 20V	290-031	KEMET
C180	.05 DISC CAP	283-010	RMC(MALLORY)
C181	10MF 20V	290-031	KEMET
C190	.05 DISC CAP	283-010	RMC(MALLORY)
C200	4.7MF 25V KEMET	290-023	KEMET
C230	.05 DISC CAP	283-010	RMC(MALLORY)
C231	4.7MF 25V KEMET	290-023	KEMET
C240	39PF	281-531	ARCO
C241	39PF	281-531	ARCO
C242	22PF	281-530	ARCO
C250	47PF	281-532	ARCO
C251	5.5-18PF	281-011	ERIE
C252	.001 ±5%	290-018	MALLORY
C253	.01 ±5%	290-019	
C254	.1 ±5%	290-021	ELPAC
C255	1MF ±5%	290-022	ELPAC
C256	10MF 20V	290-031	KEMET
C300	10MF 20V	290-031	KEMET
C310	120PF	281-534	ARCO
C350	47PF	281-532	ARCO
C351	4.7PF 25V	290-031	KEMET
C360	4.7PF 25V	290-031	KEMET
C420	10PF	281-529	ARCO
C430	10PF	281-529	ARCO
C440	10MF 20V	290-031	KEMET
C441	.05 DISC CAP	283-010	RMC(MALLORY)
C442	82PF	281-533	ARCO
C450	10PF	281-529	ARCO
C451	10PF	281-529	ARCO
C452	22PF	281-530	ARCO
C460	4.7PF 25V	290-023	KEMET

CIRCUIT REF	DESCRIPTION	EXACT PART	MFG
C470	22PF	281-530	ARCO
C471	10PF	281-529	ARCO
C472	4.7MF 25V KEMET	290-023	KEMET
C500	4.7MF 25V KEMET	290-023	KEMET
C5011	4.7MF 25V KEMET	290-023	KEMET
C530	22PF	2810530	ARCO
C540	10MF 20V	290-031	KEMET
C560	.01 DISC CAP	283-005	RMC(MAL
C561	4.7MF 25V KEMET	290-023	KEMET
C570	.01 DISC CAP	283-005	RMC(MAL
C571	4.7MF 25V KEMET	290-023	KEMET
C600	.001 DISC CAP	283-000	RMC(MAL
C610	22PF	281-530	ARCO
C620	10MF 20V	290-031	KEMET
C621	22PF	281-530	ARCO
C622	4.7MF 25V KEMET	290-023	KEMET
C630	10MF 20V	290-031	KEMET
C631	4.7M 25V KEMET	290-023	KEMET
C640	82PF	281-533	ARCO

DIODES

D100	MDA 930 A-3	152-047	MTR
D110	MDA 930 A-3	152-047	MTR
D120	1N914	152-028	CD
D160	1N914	152-028	CD
D161	1N935	152-048	MTR
D200	1N914	152-028	CD
D201	1N914	152-028	CD
D203	1N914	152-028	CD
D204	1N914	152-028	CD
D250	1N914	152-028	CD
D270	1N914	152-028	CD
D310	1N914	152-028	CD
D311	1N914	152-028	CD
D320	1N914	152-028	CD
D321	1N914	152-028	CD
D322	1N914	152-028	CD
D323	1N914	152-028	CD
D330	1N914	152-028	CD
D331	1N914	152-028	CD
D332	1N914	152-028	CD
D333	1N914	152-028	CD
D334	1N914	152-028	CD
D340	1N914	152-028	CD

CIRCUIT REF	DESCRIPTION	EXACT PART	MFG
D341	1N914	152-028	CD
D342	1N914	152-028	CD
D343	1N914	152-028	CD
D344	1N914	152-028	CD
D345	1N914	152-028	CD
D350	1N914	152-028	CD
D360	1N914	152-028	CD
D361	1N914	152-028	CD
D362	1N914	152-028	CD
D363	1N914	152-028	CD
D364	1N914	152-028	CD
D440	1ZF11T10 11V ±10%	152-023	IR
D441	1N935	152-048	MTR
D442	1N914	152-028	CD
D443	1N914	152-028	CD
D444	1N914	152-028	CD
D450	1N914	152-028	CD
D451	1N914	152-028	CD
D452	1N914	152-028	CD
D460	1N914	152-028	CD
D461	1N914	152-028	CD
D462	1N914	152-028	CD
D470	1N914	152-028	CD
D471	1N914	152-028	CD
D472	1N914	152-028	CD
D540	1ZF11T10 11V ±10%	152-023	IR
D560	1N914	152-028	CD
D570	1N914	152-028	CD
D620	T155	152-009	TI
D621	1N753 6.2V	152-003	TI
D630	1N753 6.2V	152-003	TI
D631	T155	152-009	TI
D640	1N914	152-028	CD
D641	1N914	152-028	CD
D650	1N914	152-028	CD
D651	1N914	152-028	CD

CIRCUIT REF.	DESCRIPTION	EXACT PART	MFG
	RESISTORS		
R100	10K 1/2W 5% COMP	301-103	AB
R110	10K 1/2W 5% COMP	301-103	AB
R120	1.6K 1/2W 5% COMP	301-162	AB
R121	6.8K 1/2W 5% COMP	301-687	AB
R122	6.2K 1/2W 5% COMP	301-622	AB
R123	5.6K 1/2W 5% COMP	301-562	AB
R130	1.6K 1/2W 5% COMP	301-162	AB
R140	100Ω 1/2W 5% COMP	301-101	AB
R141	1K 1/2W 5% COMP	301-102	AB
R150	100Ω 1/2W 5% COMP	301-101	AB
R151	5.1K 1/2W 5% COMP	301-512	AB
R160	562Ω 1/2W 1% MF	310-663	IRC
R161	432Ω 1/2W 1% MF	310-560	IRC
R162	8.2K 1/2W 5% COMP	301-822	AB
R170	20K 1/2W 5% COMP	301-203	AB
R180	2K 1/2W 5% COMP	301-202	AB
R181	1.21K 1/2W 1% MF	310-646	IRC
R182	1K 1/4W ADJ POT	311-102	MALLORY
R183	4.32K 1/2W 1% MF	310-693	IRC
R184	2.49K 1/2W 1% MF	310-103	IRC
R185	4.99K 1/2W 1% MF	310-566	IRC
R190	11K 1/2W 5% COMP	301-113	AB
R191	5.1K 1/2W 5% COMP	301-512	AB
R192	200 1/4W ADJ POT	311-100	MALLORY
R193	7.50K 1/2W 1% MF	310-649	IRC
R200	12.1K 1/2W 1% MF	310-606	IRC
R201	4.7K 1/2W 5% COMP	301-472	AB
R202	1K 1/2W 5% COMP	301-102	AB
R203	1K 1/2W 5% COMP	301-102	AB
R204	1K 1/4W ADJ POT	311-102	MALLORY
R205	100Ω 1/2W 5% COMP	301-101	AB
R206	2.80K 1/2W 1% MF	310-563	IRC
R207	500Ω 1/4W ADJ POT	311-101	MALLORY
R208	1.65K 1/2W 1% MF	310-106	MALLORY
R209	5K 1/4W ADJ POT	311-103	MALLORY
R210	21K 1/2W 1% MF	310-567	IRC
R211	5K 1/4W ADJ POT	311-103	MALLORY
R212	21K 1/2W 1% MF	310-567	IRC
R213	5K 1/4W ADJ POT	311-103	MALLORY
R214	21K 1/2W 1% MF	310-567	IRC
R215	5K 1/4W ADJ POT	311-103	MALLORY
R216	21K 1/2W 1% MF	310-567	IRC
R217	50K 1/4W ADJ POT	311-104	MALLORY
R218	210K 1/2W 1% MF	310-623	IRC

CIRCUIT REF.	DESCRIPTION	EXACT PART	MFG
R219	500K 1/4W ADJ POT	311-105	MALLORY
R220	2.1M 1/2W 1% MF	310-568	IRC
R221	3.5M 1/4W ADJ POT	311-106	MALLORY
R222	21M 1/2W 1% MF	310-569	IRC
R230	4.7K 1/2W 5% COMP	301-472	AB
R231	12.1K 1/2W 1% MF	310-606	IRC
R232	3.32K 1/2W 1%	310-122	IRC
R233	10K 1/2W 1% MF	310-600	IRC
R234	500Ω 1/4W ADJ POT	311-101	MALLORY
R235	10K 1/2W 1% MF	310-600	IRC
R240	330Ω 1/2W 1% MF	301-331	AB
R241	330Ω 1/2W 1% MF	301-331	AB
R242	150Ω 1/2W 1% MF	301-151	AB
R243	680Ω 1/2W 1% MF	301-681	AB
R244	150Ω 1/2W 1% MF	301-151	AB
R245	3.9K 1/2W 1% MF	301-392	AB
R250	150Ω 1/2W 1% MF	301-151	AB
R251	3.9K 1/2W 1% MF	301-392	AB
R252	15Ω 1/2W 1% MF	301-150	AB
R270	15Ω 1/2W 1% MF	301-150	AB
R271	2.7K 1/2W 1% MF	301-272	AB
R272	150Ω 1/2W 1% MF	301-151	AB
R300	1.8K 1/2W 5% COMP	301-182	AB
R301	12K 1/2W 5% COMP	301-123	AB
R302	3K 1/2W 5% COMP	301-302	AB
R303	100Ω ADJ POT	311-099	MALLORY
R310	47Ω 1/2W 5%	301-470	AB
R311	976Ω 1/2W 1% MF	310-561	IRC
R312	562Ω 1/2W 5% MF	310-663	IRC
R313	3.65K 1/2W 5% MF	310-564	IRC
R320	383Ω 1/2W 5% MF	310-559	IRC
R321	3.65K 1/2W 5% MF	310-564	IRC
R322	4.75K 1/2W 5% MF	310-599	IRC
R323	500Ω 1/4W ADJ POT	311-101	MALLORY
R324	500Ω 1/4W ADJ POT	311-101	MALLORY
R325	4.75K 1/2W 1% COMP	310-599	IRC
R330	3.3K 1/2W 1% COMP	301-332	AB
R331	10Ω 1/2W 1% COMP	301-100	AB
R332	1K 1/2W 1% COMP	301-102	AB
R340	3.3K 1/2W 1% COMP	301-332	AB
R341	10Ω 1/2W 1% COMP	301-100	AB
R350	5.6K 1/2W 1% COMP	301-562	AB
R351	100Ω 1/2W 1% COMP	301-101	AB
R352	15Ω 1/2W 1% COMP	301-150	AB
R353	330Ω 1/2W 1% COMP	301-331	AB
R360	5.6K 1/2W 1% COMP	301-562	AB
R361	15Ω 1/2W 1% COMP	301-150	AB

CIRCUIT REF.	DESCRIPTION	EXACT PART	MFG
R362	100Ω 1/2W 1% COMP	301-101	AB
R363	3.92K 1/2W 1% MF	310-123	IRC
R364	500Ω 1/4W ADJ POT	311-101	MALLORY
R365	500Ω 1/4W ADJ POT	311-101	MALLORY
R366	3.92K 1/2W 1% MF	310-123	IRC
R400	3.92K 1/2W 1% MF	310-123	IRC
R401	200Ω 1/4W ADJ POT	311-100	MALLORY
R402	562Ω 1/2W 1% MF	310-663	IRC
R410	3.92K 1/2W 1% MF	310-123	IRC
R411	1K 1/2W 5% COMP	301-102	AB
R412	100Ω 1/2W 5% COMP	301-101	AB
R413	200Ω 1/4W ADJ POT	311-100	MALLORY
R414	3.9K 1/2W 5% COMP	301-392	AB
R420	910Ω 1/2W 5% COMP	301-911	AB
R421	150Ω 1/2W 5% COMP	301-151	AB
R422	3K 1/2W 5% COMP	301-302	AB
R430	150Ω 1/2W 5% COMP	301-151	AB
R431	3K 1/2W 5% COMP	301-302	AB
R440	750Ω 1/2W 5% COMP	301-751	AB
R441	1K 1/2W 5% COMP	301-102	AB
R442	100Ω 1/2W 5% COMP	301-101	AB
R443	121Ω 1/2W 1% MF	310-557	IRC
R444	221Ω 1/2W 1% MF	310-558	IRC
R445	267Ω 1/2W 1% MF	310-120	IRC
R450	47Ω 1/2W 5% COMP	301-470	AB
R451	121Ω 1/2W 1% MF	310-557	IRC
R452	825Ω 1/2W 1% MF	310-647	IRC
R453	221Ω 1/2W 1% MF	310-558	IRC
R454	3.32K 1/2W 1% MF	310-122	IRC
R455	267Ω 1/2W 1% MF	310-120	IRC
R456	3.92K 1/2W 1% MF	310-123	IRC
R460	100Ω 1/2W 5% COMP	301-101	AB
R461	15Ω 1/2W 5% COMP	301-150	AB
R462	562Ω 1/2W 1% MF	310-663	IRC
R463	475Ω 1/2W 1% MF	310-118	IRC
R470	15Ω 1/2W 5% COMP	301-150	AB
R471	100Ω 1/2W 5% COMP	301-101	AB
R472	2.21K 1/2W 1% MF	310-607	IRC
R473	360Ω 1/2W 5% COMP	301-361	AB
R474	1K 1/2W 5% COMP	301-102	AB
R475	33Ω 1/2W 5% COMP	301-330	AB
R476	562Ω 1/2W 1% MF	310-663	IRC
R477	475Ω 1/2W 1% MF	310-118	IRC
R478	8.25K 1/2W 1% MF	310-604	IRC

CIRCUIT REF.	DESCRIPTION	EXACT PART	MFG
R500	500Ω 1/4W ADJ POT	311-101	MALLORY
R501	1K 1/2W 1% MF	310-605	IRC
R502	1K 1/2W 5% COMP	301-102	AB
R503	3.92K 1/2W 1% MF	310-123	IRC
R504	200Ω 1/4W ADJ POT	311-100	MALLORY
R505	3.9K 1/2W 5% COMP	301-392	AB
R510	3.92K 1/2W 1% MF	310-123	IRC
R511	1K 1/2W 5% COMP	301-102	AB
R520	910Ω 1/2W 5% COMP	301-911	AB
R521	3.9K 1/2W 5% COMP	301-392	AB
R530	150Ω 1/2W 5% COMP	301-151	AB
R540	750Ω 1/2W 5% COMP	301-751	AB
R541	1K 1/2W 5% COMP	301-102	AB
R550	47Ω 1/2W 5% COMP	301-470	AB
R551	3.9K 1/2W 5% COMP	301-392	AB
R560	100Ω 1/2W 5% COMP	301-101	AB
R561	5.6K 1/2W 5% COMP	301-562	AB
R562	15Ω 1/2W 5% COMP	301-150	AB
R570	15Ω 1/2W 5% COMP	310-150	AB
R571	5.6K 1/2W 5% COMP	301-562	AB
R572	100Ω 1/2W 5% COMP	301-101	AB
R573	2.74K 1/2W 1% MF	310-562	IRC
R574	47Ω 1/2W 5% COMP	301-470	AB
R600	2.2K 1/2W 5% COMP	301-222	AB
R601	1K 1/2W 5% COMP	301-102	AB
R602	1K 1/2W 5% COMP	301-102	AB
R610	1K 1/2W 5% COMP	301-102	AB
R611	2.2K 1/2W 5% COMP	301-222	AB
R620	470Ω 1/2W 5% COMP	301-471	AB
R621	12K 1/2W 5% COMP	301-123	AB
R622	150Ω 1/2W 5% COMP	301-151	AB
R630	150Ω 1/2W 5% COMP	301-151	AB
R631	470Ω 1/2W 5% COMP	301-471	AB
R632	12K 1/2W 5% COMP	301-123	AB
R633	1K 1/4W ADJ POT	311-102	MALLORY
R640	4.7K 1/2W 5% COMP	301-472	AB
R641	150Ω 1/2W 5% COMP	301-151	AB
R642	15Ω 1/2W 5% COMP	301-150	AB
R643	3.9K 1/2W 5% COMP	301-392	AB
R644	1.5K 1/2W 5% COMP	301-152	AB
R650	15Ω 1/2W 5% COMP	301-150	AB
R651	47Ω 1/2W 5% COMP	301-470	AB
R652	150Ω 1/2W 5% COMP	301-151	AB
R653	4.7K 1/2W 5% COMP	301-472	AB
R654	3.9K 1/2W 5% COMP	301-392	AB

TRANSISTORS

CIRCUIT REF.	DESCRIPTION	EXACT PART	MFG
Q100	MJE371	156-047	MTR
Q110	MJE521	156-048	MTR
Q120	2N4121	156-043	FAIRCHILD
Q130	MPS6543	156-050	MTR
Q140	MJE521	156-048	MTR
Q150	MJE371	156-047	MTR
Q160	MPS6543	156-050	MTR
Q170	2N4121	156-043	FAIRCHILD
Q180	MPS6543	156-050	MTR
Q190	2N4121	156-043	FAIRCHILD
Q200	F5085 MATCHED	156-051	UC
Q230	F5085 MATCHED	156-051	UC
Q240	CA3030 IC	156-009	RCA
Q250	MPS6543	156-050	MTR
Q270	2N4121	156-043	FAIRCHILD
Q300	2N4121	156-043	FAIRCHILD
Q310	2N4250	156-049	FAIRCHILD
Q320	2N4250	156-049	FAIRCHILD
Q330	MPS6543	156-050	MTR
Q340	MPS6543	156-050	MTR
Q350	MPS6543	156-050	MTR
Q360	2N4121	156-043	FAIRCHILD
Q400	MPS6543	156-050	MTR
Q410	MPS6543	156-050	MTR
Q420	2N4121	156-043	FAIRCHILD
Q430	2N4121	156-043	FAIRCHILD
Q440	2N4121	156-043	FAIRCHILD
Q450	2N4121	156-043	FAIRCHILD
Q460	2N3643	156-021	FAIRCHILD
Q470	2N3638	156-020	FAIRCHILD
Q500	MPS6543	156-050	MTR
Q510	MPS6543	156-050	MTR
Q520	2N4121	156-043	FAIRCHILD
Q530	2N4121	156-043	FAIRCHILD
Q540	2N4121	156-043	FAIRCHILD
Q550	2N4121	156-043	FAIRCHILD
Q560	2N3643	156-021	FAIRCHILD
Q570	2N3638	156-020	FAIRCHILD
Q600	MPS6543	156-050	MTR
Q610	2N4121	156-043	FAIRCHILD
Q620	2N4121	156-043	FAIRCHILD
Q630	MPS6543	156-050	MTR
Q640	MPS6543	156-050	MTR
Q650	2N4121	156-043	FAIRCHILD

6.0.0 . . . . . PARTS LIST

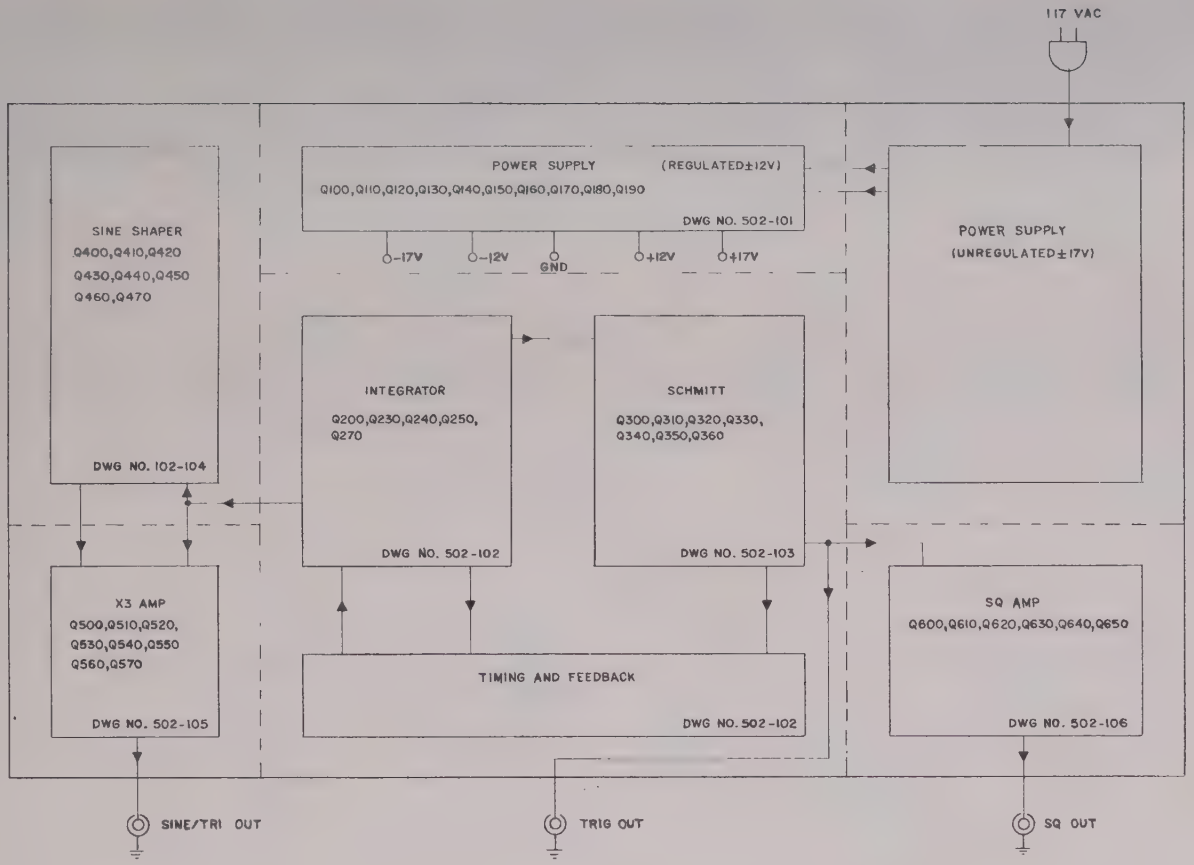
CIRCUIT REF.	DESCRIPTION	EXACT PART	MFG
	SWITCHES		
S100	1K SPST 45D102S03	311-108	IRC-CTS
S200	2P 2-11 POS SHORTING PA 2-11	260-083	CENTRALAB
S500	1P 2-11 POS NON-SHORTING PA1001	260-082	CENTRALAB
S640	1P 2-11 POS NON-SHORTING PA1001	260-082	CENTRALAB
	TRANSFORMER		
T100	24VCT 1A F45X	120-029	TRIAD
	FUSE		
F100	1/2 AMP SLO BLO	159-024	
	PILOT LIGHT		
P100	36EN1315	136-046	LEECRAFT

SECTION 7

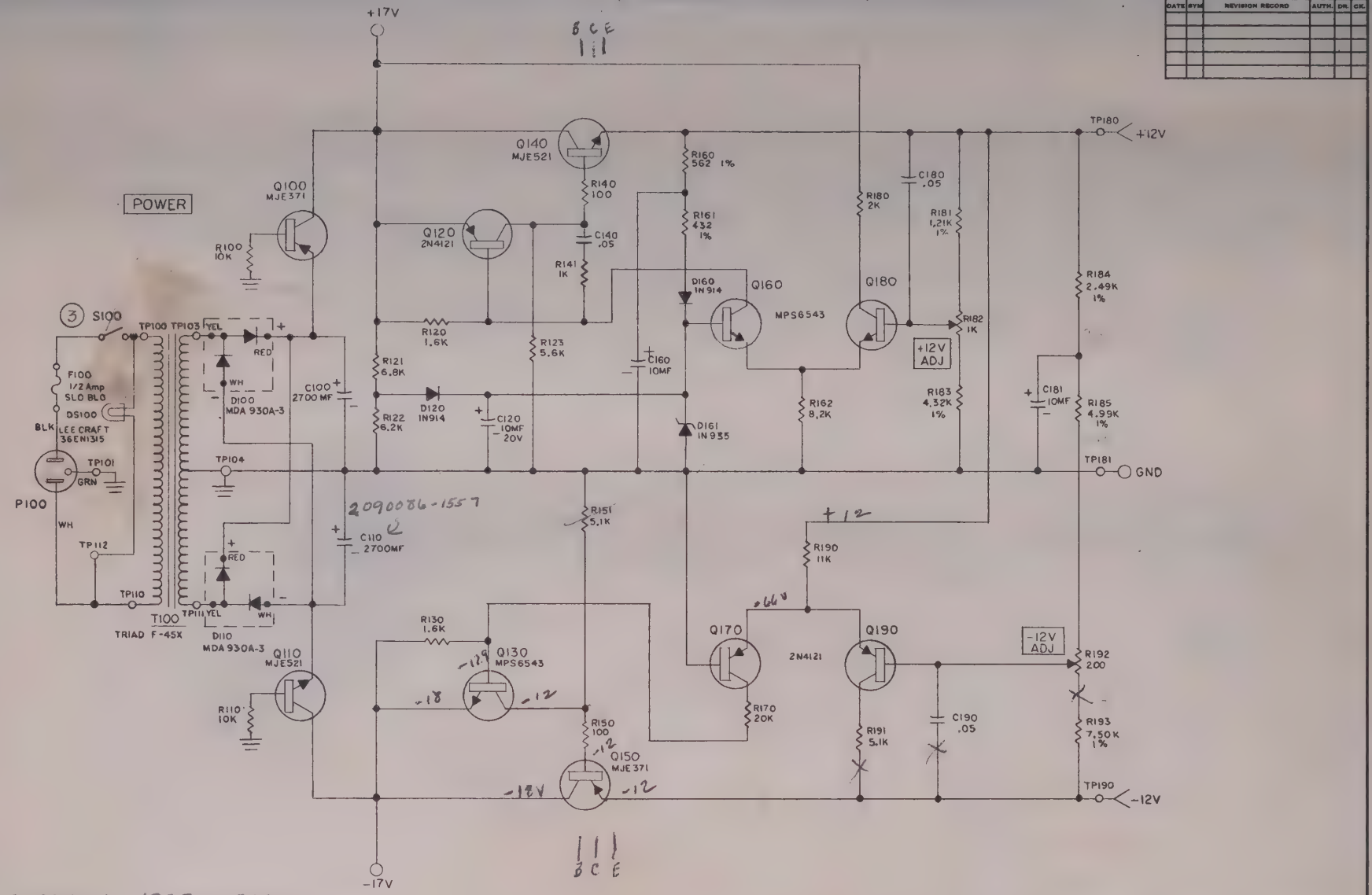
CIRCUIT DIAGRAMS

SECTION 7

DATE	BY	REVISION RECORD	AUTH.	DR.	CK.



TOLERANCES (EXCEPT AS NOTED)			
DECIMAL ±		SCALE	DRAWN BY J SVELA APPROVED BY
FRACTIONAL ±	TITLE BLOCK DIAGRAM - MODEL 502		
ANGULAR ±	DATE 9/22/67	DRAWING NUMBER 502-100	

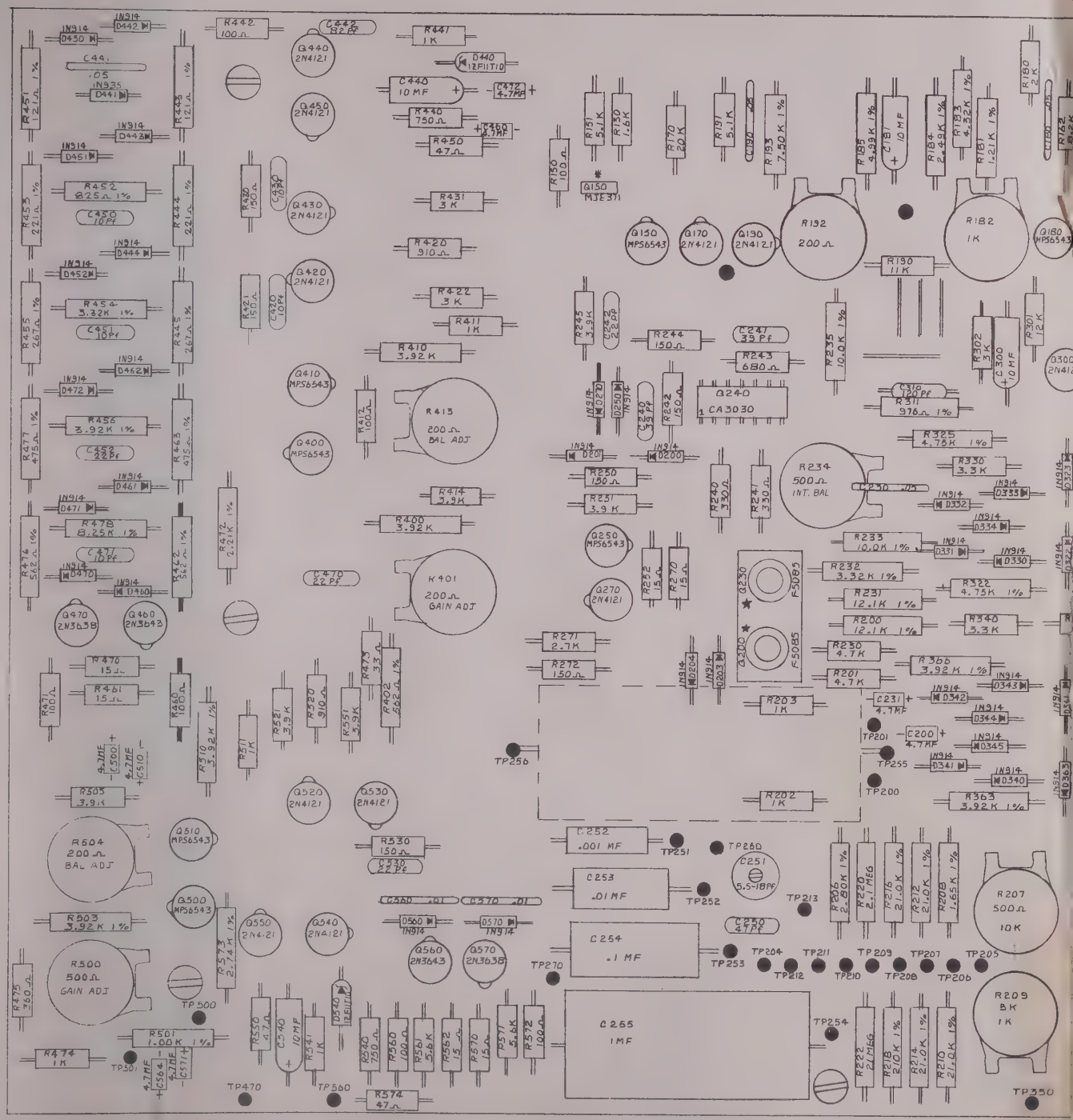


DATE	SYM	REVISION RECORD	AUTH.	DR.	CK.

3. S100 GANGED WITH R633 (ATTEN. FOR SQ FUNCTIONS)
2. ALL CAPACITOR VALUES ARE IN MFD'S
1. ALL RESISTORS ARE ½ W 5% COMP.

NOTES: UNLESS OTHERWISE SPECIFIED.

TOLERANCES (EXCEPT AS NOTED)			
DECIMAL ±		SCALE	DRAWN BY J SVELA
			APPROVED BY
FRACTIONAL ±	TITLE SCHEMATIC – POWER SUPPLY, MODEL 502		
ANGULAR ±	DATE 6-19-67	DRAWING NUMBER 502-101	



BOTTOM VIEW

8. BASE LEAD, EMITTER LEAD, COLLECTOR LEAD — LEAD CONFIGURATI

TRANS. PAD TOP VIEW

7. LOCATING TAB, BASE LEAD, COLLECTOR LEAD, NOT USED, EMITTER LEAD

6 * DENOTES SIDE WITH LETTERING

5 POSITION TRANS. PADS AS SHOWN ON ASS'Y. DRAWING

4. ★ DENOTES MATCHED PAIR (REFER TO REF. DRAWING NO. 502-300)

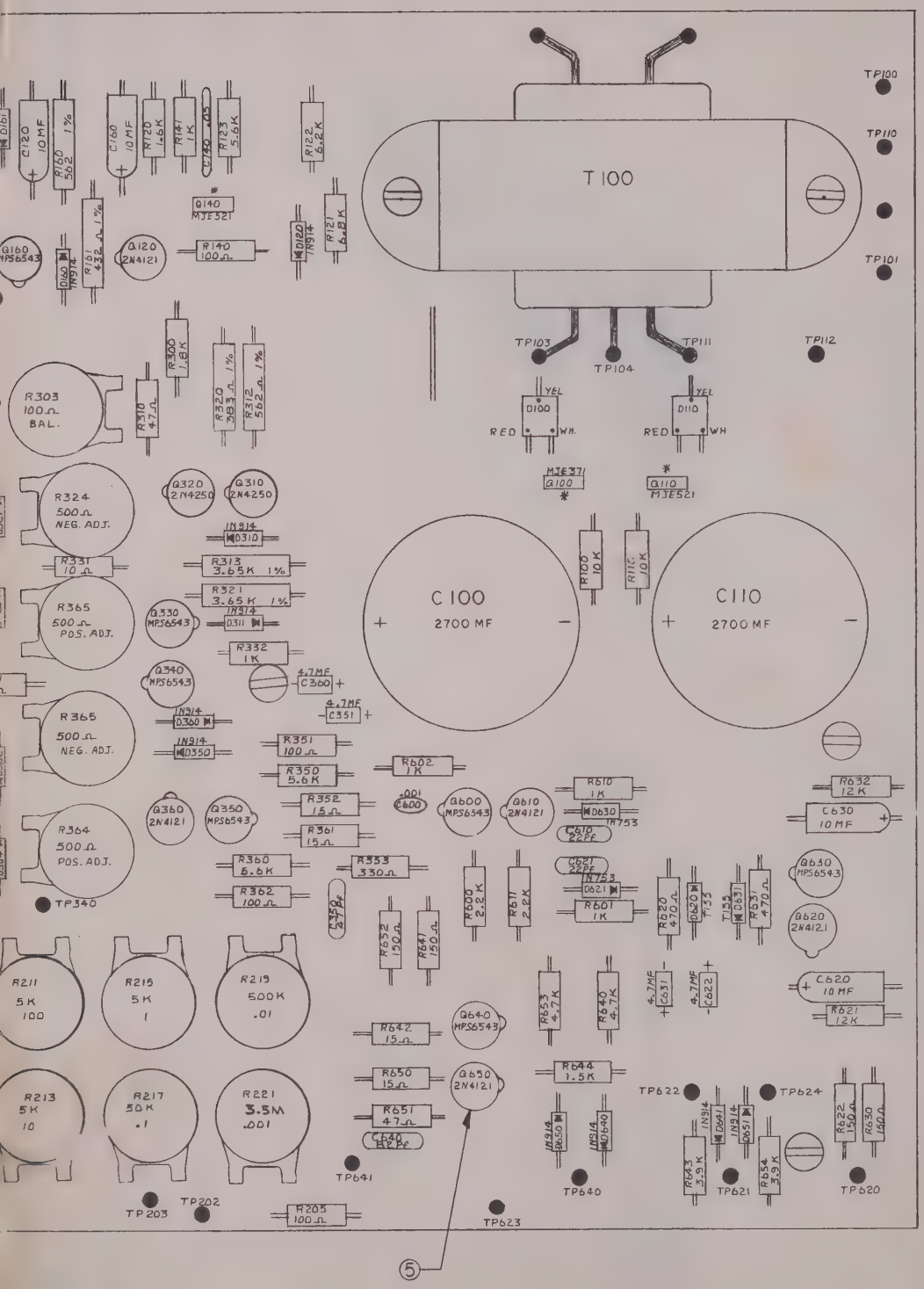
3. ALL CAPACITOR VALUES ARE IN MFD'S.

2. ALL RESISTORS ARE ½ W 5 % COMP.

1. FOR COMP. PARTS SEE BILL OF MATERIALS DWG NO 502-600

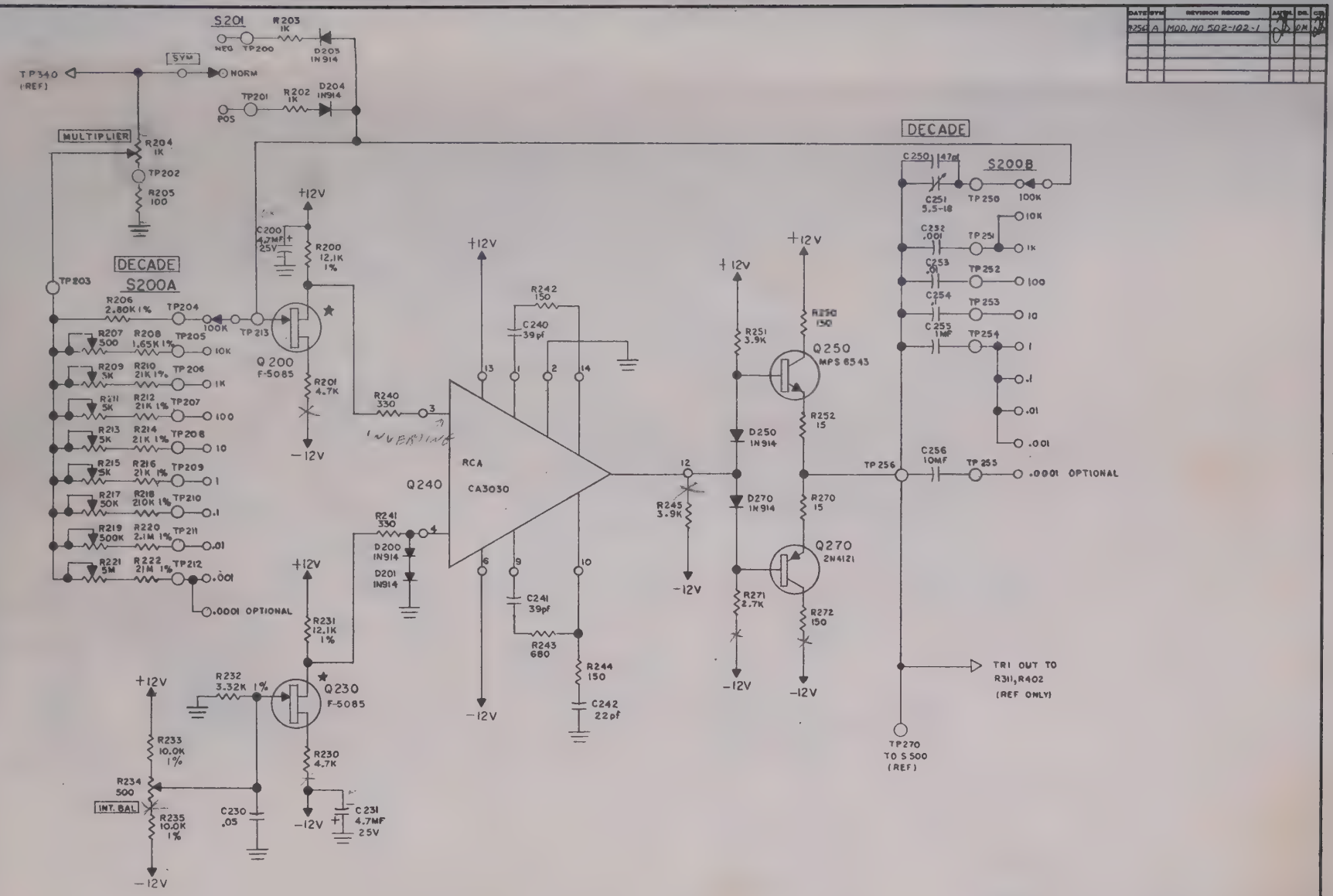
NOTES: UNLESS OTHER WISE INDICATED.

DATE	SYM	REVISION RECORD	AUTH.	DR.	CK.
6-26-67	A	MOD. NO. 502-200-1		GH	



1 FOR ALL MPS 6543 ONLY

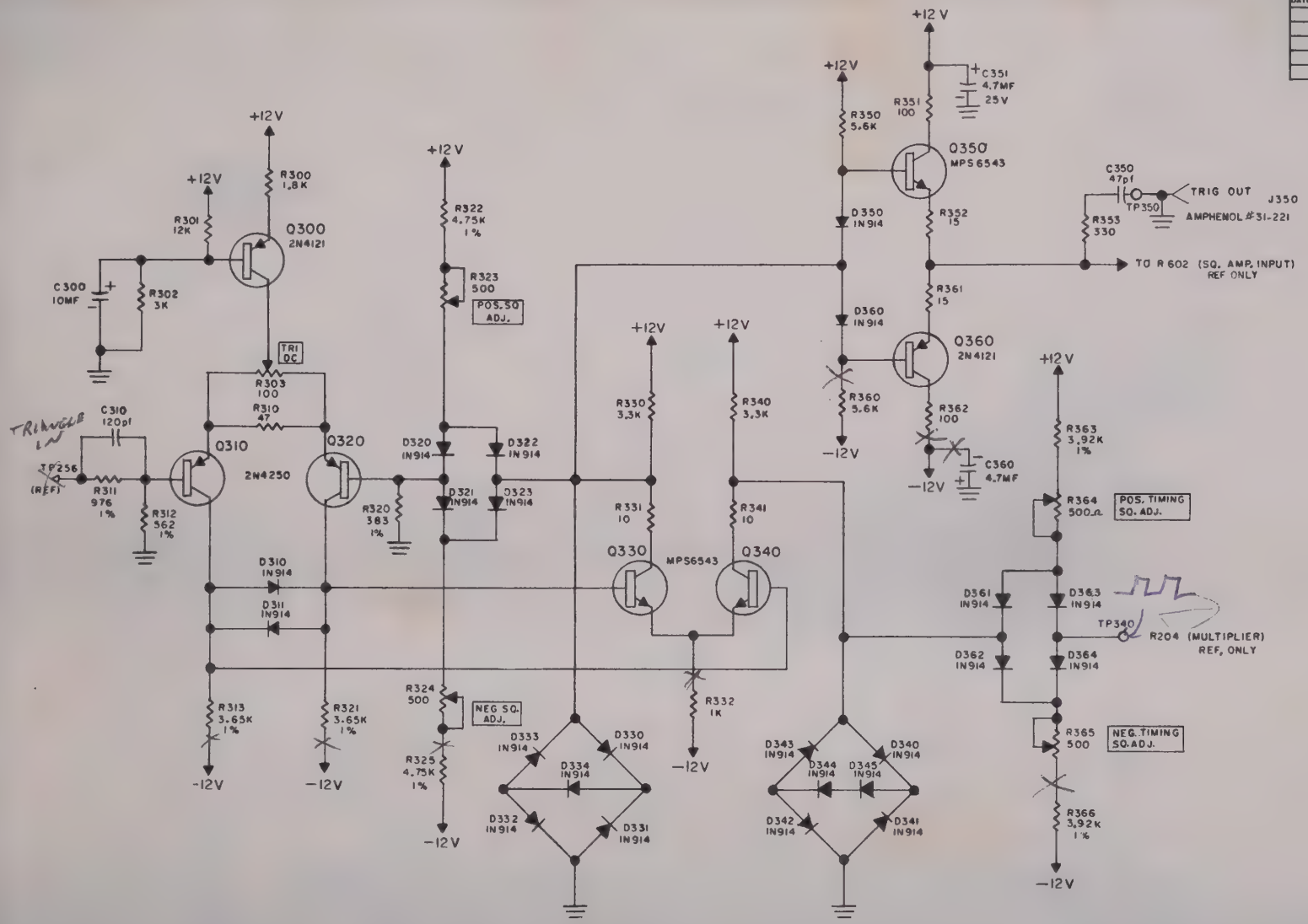
TOLERANCES (EXCEPT AS NOTED)			
DECIMAL ±		SCALE	DRAWN BY J SVELA; APPROVED BY
FRACTIONAL ±	TITLE ASSEMBY-P.C. BOARD, MODEL 502		
ANGULAR ±	DATE 6-26-67	DRAWING NUMBER 502-200	



DATE	BY	REVISION RECORD	APPR.	DR.	CH.
7256	A	MOD. NO 502-102-1		DM	

3. ★ DENOTES MATCHED PAIR. (REF DWG. NO 502-3001
2. ALL CAPACITOR VALUES ARE IN MFD'S.
1. ALL RESISTORS ARE 1/2 W 5% COMP.
NOTES: UNLESS OTHERWISE SPECIFIED.

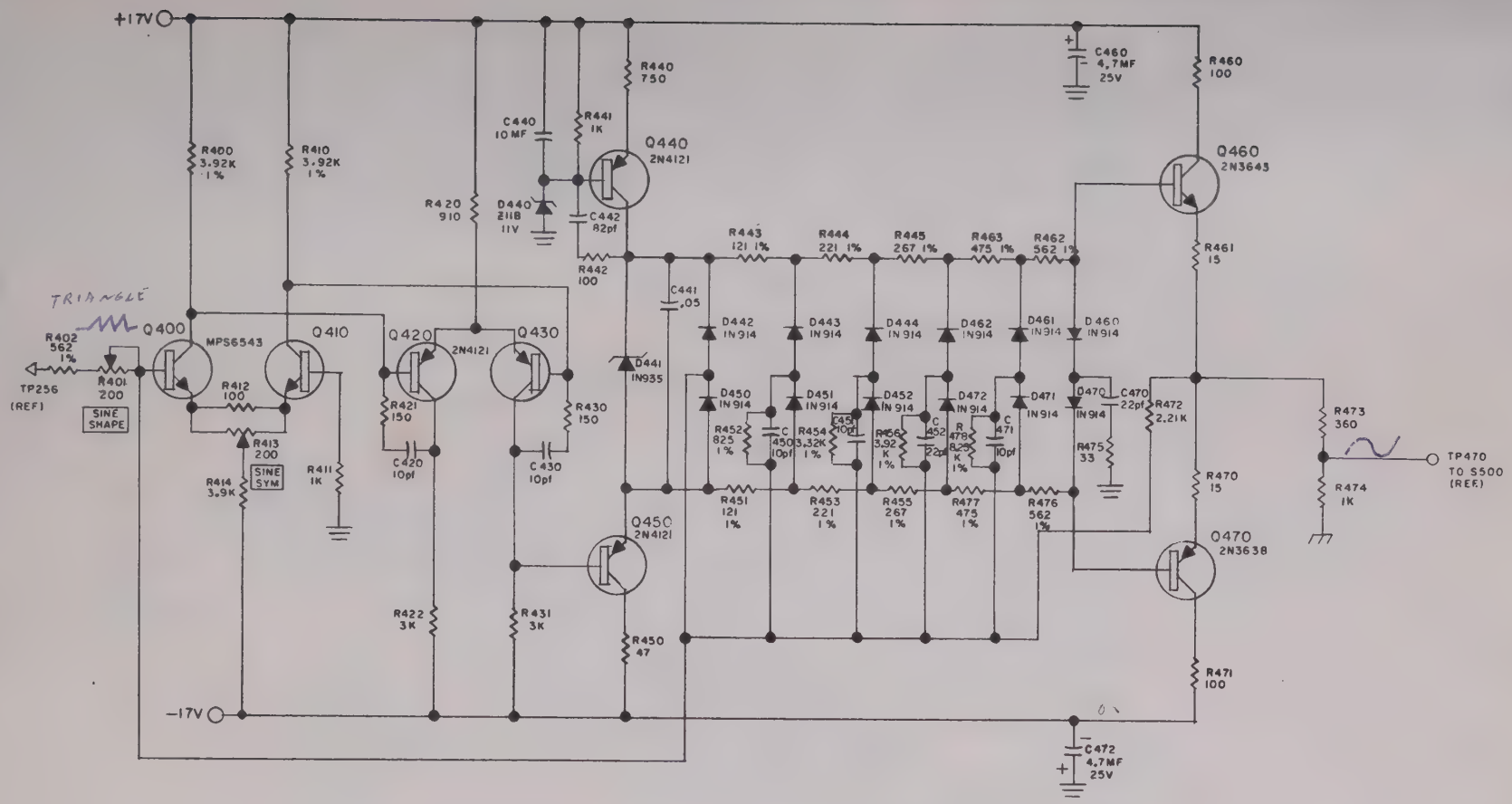
TOLERANCES (EXCEPT AS NOTED)			A
DECIMAL ±		SCALE	DRAWN BY J. SVELA
			APPROVED BY
FRACTIONAL ±	TITLE SCHEMATIC-INTEGRATOR, MODEL 502		
ANGULAR ±	DATE 5-23-67	DRAWING NUMBER 502-102	



DATE	BY	REVISION RECORD	AUTH.	DR.	CK.

2. ALL CAPACITOR VALUES ARE IN MFD'S.
1. ALL RESISTORS ARE 1/2 W 5 % COMP.
NOTES: UNLESS OTHERWISE SPECIFIED

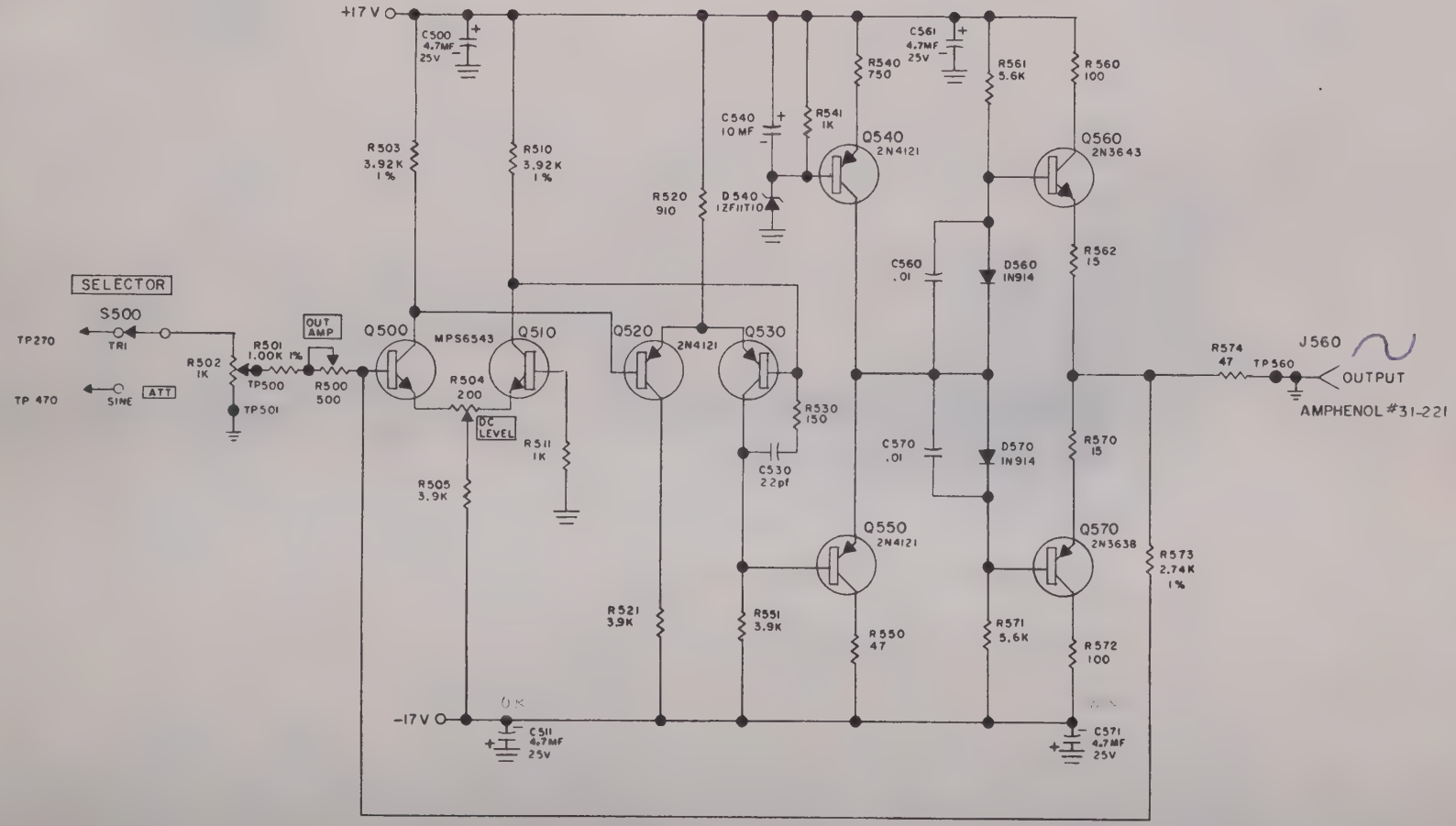
TOLERANCES (EXCEPT AS NOTED)			
DECIMAL ±		SCALE	DRAWN BY J SVELA
FRACTIONAL ±	TITLE SCHEMATIC – SCHMITT, MODEL 502		APPROVED BY
ANGULAR ±	DATE 6-19-67	DRAWING NUMBER 502-103	



2. ALL CAPACITOR VALUES ARE IN MFD'S.
1. ALL RESISTORS ARE 1/2 W 5% COMP.
NOTES: UNLESS OTHERWISE SPECIFIED.

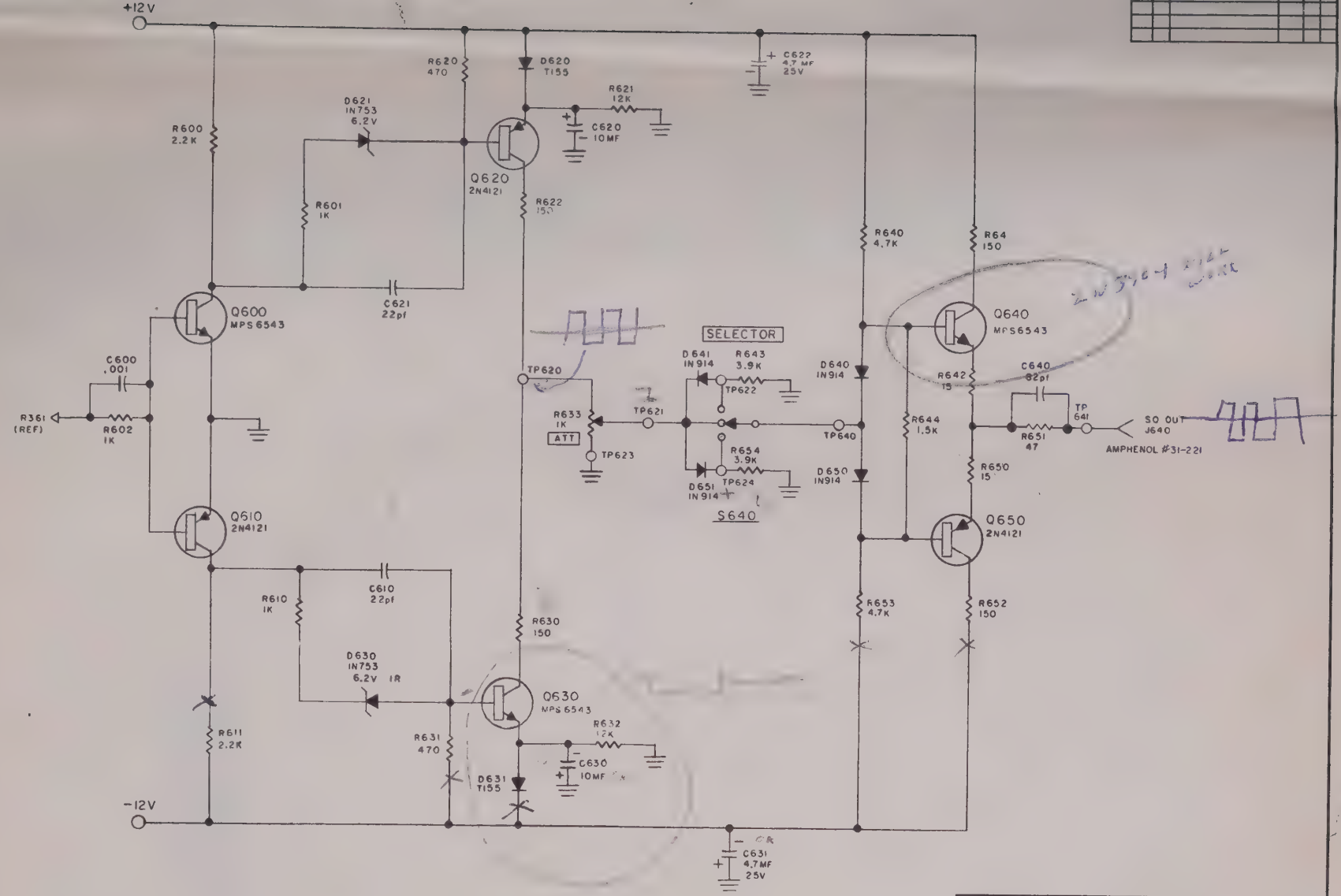
TOLERANCES (EXCEPT AS NOTED)			
DECIMAL ±		SCALE	DRAWN BY J. SVELA
			APPROVED BY
FRACTIONAL ±	TITLE SCHEMATIC – SINE SHAPER, MODEL 502		
ANGULAR ±	DATE 6-19-67	DRAWING NUMBER 502-104	

DATE	BY	REVISION RECORD	AUTH.	DR.	CK.



2. ALL CAPACITOR VALUES ARE IN MFD'S.
1. ALL RESISTORS ARE 1/2W 5% COMP.

TOLERANCES (UNLESS OTHERWISE SPECIFIED)			
DECIMAL ±		SCALE	DRAWN BY J. SVELA
FRACTIONAL ±	TITLE SCHEMATIC – X 3 AMP, MODEL 502		APPROVED BY



2. ALL CAPACITORS ARE IN MFD'S.
1. ALL RESISTORS ARE 1/2 W 5% COMP.
NOTES: UNLESS OTHERWISE SPECIFIED.

TOLERANCES (EXCEPT AS NOTED)			
DECIMAL ±		SCALE	DRAWN BY J SVELA
			APPROVED BY
FRACTIONAL ±	TITLE SCHEMATIC—SQ. AMP, MODEL 502		
ANGULAR ±	DATE 6-19-67	DRAWING NUMBER 502-106	

SECTION 8

REPRESENTATIVES AND DISTRIBUTORS

SECTION 8

FROM
TP256

US DATA ASSOC INC
214-661-9633
14241 PROTON
DALLAS, TX 75240

EXACT ELECTRONICS, INC. - REPRESENTATIVES AND DISTRIBUTORS

EASTERN U.S.

Martin P. Andrews, Inc. 319 Mott Road, Fayetteville, New York 13066 (315) 637-6405	New York State (not NYC)
Fact-Tronics P. O. Box 745, Casselberry, Florida 32707 (305) 838-5607	Fla, Ga, Tenn., Miss.
P. O. Box 1135, Huntsville, Alabama (205) 539-7193	Ala, S. Carolina
NLR Associates, Inc. 617 Bloomfield Ave., Verona, New Jersey 07044 (201) 239-4748	NYC, upper N.J.
C. E. Snow Co. 3720 Farragut St., Kensington, Maryland 20795 (301) 949-1010	Wash DC, Va.
Friendship Airport Terminal Bldg., Baltimore, Md (301) 761-5757	Maryland
1349 W. Cheltenham Ave., Philadelphia, Pa (215) 224-2626	S. New Jersey, E. Pa., Dela
Technical Instruments, Inc. 122 West Street, Wilmington, Mass (617) 944-3930	Mass., Maine, Vt., New Hampshire
575 Broad Street, Bridgeport, Connecticut (203) 368-4582	Conn., R.I.

CENTRAL U.S.

Bard Associates, Inc. La Grange Indust. Park, La Grange, Illinois (312) 354-0660	Ill, Iowa, Wisc.
4002 Meadows Drive, Indianapolis, Ind 462205 (317) 849-2723	Indiana
7700 Morgan Ave., S., Minneapolis, Minn 55423 (612) 866-1700	Minnesota
Southwest Electronic Industries, Inc. 621 Meadows Bldg., Dallas, Texas 65206 (214) 363-1671	N. Texas, Okla, Ark, N. La.
1405 S. Post Oak Road, Houston, Texas 77027 (713) 621-3760	S. Texas, S. La.
S. Sterling Co. 21250 10-1/2 Mile Road, Southfield, Michigan (313) 357-3700	Michigan
5827 Mayfield Road, Cleveland, Ohio (216) 442-8080	E. Ohio
2673 Culver Ave., Dayton, Ohio 45429 (513) 298-7573	W. Ohio
4232 Brownsville Road, Pittsburgh, Pa 15227 (412) 884-5515	W. Pa, W. Virginia
11734 Lackland Industrial Dr., St. Louis, Mo 63141 (314) 542-3636	Mo, Kansas, Nebraska

WESTERN U.S.

Hytronic Measurements, Inc. 4940 E. 39th, Denver, Colorado 80207 (303) 388-4081	Colo, Wyo, Montana
205 San Pablo S.E., Albuquerque, N.M. 87108 (505) 268-3941	New Mexico
1017 N. Third St., Phoenix, Arizona 85004 (602) 253-6104	Arizona
2022 S. Main St., Salt Lake City, Utah 84115 (801) 466-4924	Idaho, Utah

CONTINUED

WESTERN U.S. (CONTINUED)

THE ABCO COMPANY
555 W. NINTH ST., SAN PEDRO, CALIF 90731 (213) 833-8333 S. CALIFORNIA

THE MAULDIN COMPANY
441 CALIFORNIA AVE., PALO ALTO, CALIFORNIA 94306 (415) 326-5291 N. CARLIFORNIA

BRENNAN ASSOCIATES
208 CARLSON BLDG., BELLEVUE, WASHINGTON 98004 (206) 454-9332 WASHINGTON, OREGON

CANADA

EXACT ELECTRONICS, INC.
P. O. BOX 160, HILLSBORO, OREGON 97123 (503) 648-6661

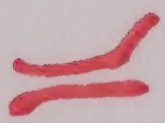
EXACT ELECTRONICS, INC. - OVERSEAS DISTRIBUTORS

COASIN, S.A., Virrey del Pino 4071, Buenos Aires	Argentina
Electronic Associates, Pty., Ltd., 87 Alexander St., Crows Nest, NSW, Sydney	Australia
Inglomark Markowitsch & Co., Mariahilfer Strasse 133, Wien XV	Austria
Regulation Mesure sprl, 22 Rue Saint-Hubert, Bruxelles 15	Belgium
Importacio Industria e Commercio, Ambries SA, Ave Grace Aranha, 226-6°, Rio de Janeiro	Brazil
Pentz & Cia, Ltda, Casilla 2839, Santiago	Chile
Oltronix A/S, Maltegaardsvej 18a, Gentofte	Denmark
Advance Electronics, Ltd., Roebuck Rd., Hainault, Ilford	England
INTO Y/O, P. O. Box 10153, 11 Maritullinkatu, Helsinki	Finland
S.E.R.I.E.L. (SA), 48, Avenue Victor Hugo, Clamart (Seine)	France
Marios Dalleggio Representations, 2 Alopekis Street, Athens 139	Greece
Industrial Agencies, 11 Mahatma Gandhi Road, Bombay 1	India
Abdul Masih E. Jwaideh, 85, Saadun Street, Bagdad	Iraq
Eastronics Ltd., 75 Haifa Rd., P. O. Box 21029, Tel Aviv	Israel
Silverstar Ltd., Via Dei Gracchi 20, 1-20146 Milano	Italy
Midoriya Electric Co., Ltd. 3, 2-Chome, Kyobashi, Chui, Tokyo	Japan
FREDIN, SA, P O Box 53-958, Mexico 17, D.F.	Mexico
C. N. Rood, n.v. 11-13 Cort Van Der Lindenstraat, Rijswijk(ZH)	The Netherlands
W & K McLean Ltd., P. O. Box 3097, Auckland	New Zealand
Morgenstierne & Co., A/S Ingenirfirma, Wessels Gate 6, Oslo	Norway
Pakland Corporation, Central Commercial Area, P.E.C.H. Society, Karachi 29	Pakistan
Equipamentos de Laboratorio Lda, Rua Pedro Nunes 47, Lisbon 1 (also Angola, Mozambique, Africa)	Portugal
Telco, S.L., Gravina 27, Madrid	Spain
Scandia Metric AB, S. Langgatan 22, Fack Solna 3, Stockholm	Sweden
Omni Ray AG, Dufourstrasse 56, Zurich 8008	Switzerland
Rohde and Schwarz Vertriebs - GmbH, Hohe Strasse 160-168, Koeln	West Germany

Nov. 1967

SECTION 9

ADDENDA



SECTION 9